MYANMAR LAVENDER JADIETE:

COLOR ANALYSIS

KATHERINE PALTHEY

Grasse, France

GEM-A Student 811145

March 2016

Table of Contents

INTRODUCTION

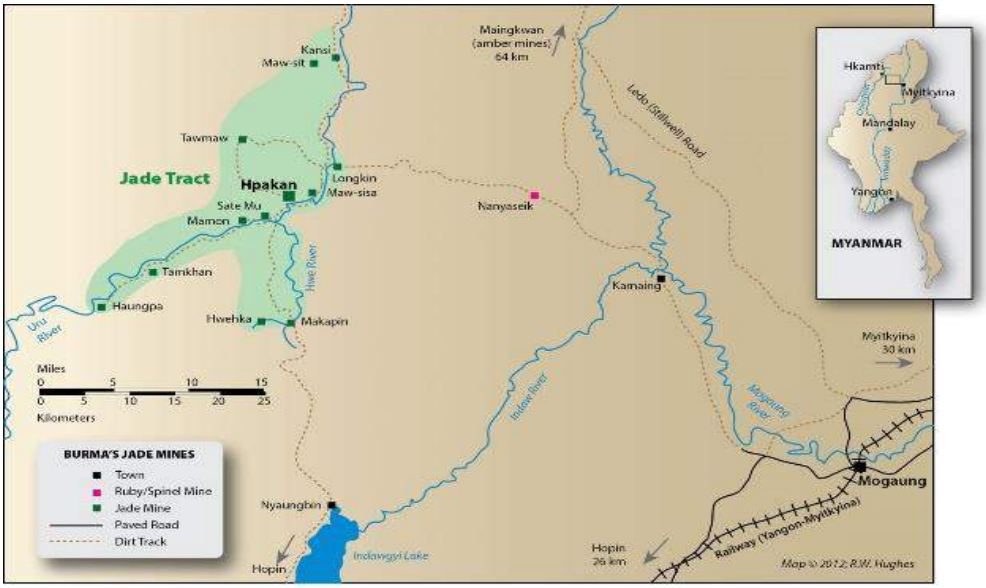
My project focusses on Myanmar lavender jadeite and how to distinguish natural lavender A-jadeite colored by manganese (Mn) based on gemological and reflectance spectrum analysis. I will first present an overall descriptive of Jadeite and its mineral specifications pointing out features that are most desirable when evaluating jade. I will then discuss the differences between Grade A, B and C Lavender Jadeite and will present various gemological testing methods that help to analyze and identify natural lavender jadeite. I will then present a collection of fifty-five samples, the majority purchased as "natural lavender jade" in Mae Sot on the Myanmar border in March 2015. Their respective gemological properties and reflectance spectrums are reported here. Interestingly enough, although purchased together, the lavender colored jade showed several different spectrums. After completing these tests, the samples were organized into five separate groups based on the similarity of their absorption spectrums. I will distinguish the manganese colored lavender jadeite from the other color origins found within these sample groups. To conclude, I will suggest possible causes for the differences in color origin found in these Myanmar jade samples.

Jadeite and its Origin

Jadeite is derived from the Spanish word "Piedra de Ijada" or "Loin Stone" for its long time use in curing loins and kidneys. For over 2000 years, Jadeite has been known as the noblest gemstone in China with specific meanings, symbolism and spirituality. Jadeite is a polycrystalline aggregate that belongs to the Pyroxene group of minerals that contains Diopside. Jadeite is a Silicate mineral found in metamorphic rocks that requires high pressure and relatively low temperatures to crystallize. Its chemical composition is $NaAl(SiO3)2$: Sodium Aluminum Silicate with cleavage at 90°. Jadeite is a monoclinic crystal with a silica tetrahedral form containing single chains. Silicate minerals containing chains are also referred to as *Inosilicate*. Jadeite is Inosilicate as it forms chains consisting of a silicon to oxygen atom ratio of 1:3. Jadeite consists of interlocking prismatic feathery pyroxene crystals that range in length from 10 microns to over a centimeter (Hughes, 2000).

Jadeite is allochromatic: it is transparent and colorless when pure. The color and translucence of natural Jadeite are the result of the chemical impurities present in the rough and the rate at which the jade cooled during the formation process. "Various chromophores including single transition metal ions $Mn3+$, $Mn2+$, $Ti3+$, $Fe3+$ and $V3+$ and paired charge-transfer ions $Fe2+$-$Fe3+$ and $Ti4+$-$Fe2+$ have been proposed based on UV-visible spectroscopic data, chemical analysis and comparisons to similarly colored minerals. (Rossman (1974), Shinno and Oba (1993), Chen et al (1999), Ouyang (2001) and Harlow and Shi, (2011)". (Ren Lu) Jadeites Refractive Index is 1,64 to 1,68 and has a Specific Gravity between 3,30 and 3,36. The primary source of Lavender Jadeite is from the northern part of Myanmar along the URA River area. The mining areas for

jadeite are between Kansi (North) and Haungpa (Southwest) and Makapen (Southeast). Hpaken is now the main center of this mining district. Jadeite is found in alluvial deposits in the form of blocks and galets. Myanmar Jadeite ranges in color from white and yellow to lavender, red and black and all shades of green.



Jade Tract in Myanmar: Follows along the URA River

Myanmar Jadeite

Myanmar Jadeite have a wide variety in texture and mineral content. Researchers who have studied various classifications have recommended to classify Myanmar Jade into three main categories:

1) Jadeite Jade
2) Kosmochlor Jade or
3) Omphacite Jade. (darker and less transparent than jadeite)

Under Chinas regulation, any rock containing one or more of Jadeite, Kosmochlor and/or Omphacite can be sold as jade in the marketplace (Franz, 2014). These three types of jade can be distinguished best by Raman and Infrared Spectroscopy, but this is quite costly, so rarely confirmed. Gemological properties of natural, treated and synthetic jadeite has already been discussed in detail by Koivula (1982), Nassau and Shigley (1987) and Lu (2012). My project focusses on the first category: Jadeite jade lavender color from Myanmar. The other

colored jadeite are not discussed here unless to demonstrate how they differ under examination.

Lavender jadeite from northern Myanmar occurs along the intersection of the Burmese Western and Eastern provinces along an offset of the Sagaing Fault. The primary occurrences of jadeite consist of veins within serpentines which formed by crystallization from fluids during high-pressure low temperature metamorphism. The "Jade Tract" is characterized by bodies of serpentinized peridotite which are surrounded by crystalline schists and plutonic rocks. These veins were generated by the subduction of the Indian Plate underneath the Asian continent. In other words, as one plate is forced under the other, this becomes a "subduction zone" and causes the mountain range seen today for example in Myanmar (chapter 9: The Geology of Gems).

Jadeite was formed independently by the crystallization from hydrous fluids that were formed in fractures at high pressure and low temperatures. Jadeite rises through dikes which are shallow intrusions which extend practically vertical into the existing rock. Manganese mixed in with the serpentinite only at the late stages to produce the lavender color jadeite. In the Sagaing Fault, there was a shift from this vertical thrusting to lateral faulting which helped in the upbringing and exposure of jadeite in Myanmars Hpaken area. Thirty three samples in this study were collected along the border in Mae Sot, a small town between Thailand and Myanmar where jadeite is readily sold after being mined and brought down from this "Jade Tract" district. My research investigates further into their true color origins…

Shades of Lavender colored jadeite samples: Color origin?

Classifying Grade A, B or C Jade

The first step in determining the quality of natural jade is classifying it either *Grade A, B or C Jade*. According to Jiajun et al., the best way to identify A-jade from B-jade and Grade them accordingly include:

Grade A Jade: natural untreated jadeite jade; normal polishing and colorless waxing: most often beeswax is used to fill the stone's microscopic surface pores.

Grade B Jade: acid bleached, polymer impregnated jadeite jade; this improves color by bleaching the stains and darker colored inclusions. The bleaching however destroys the structure of the stone, so the polymer filling helps reinforce the strength and durability.

Grade C Jade: acid bleached, polymer impregnated dyed jadeite jade; this is Grade B jade with a dyed color added. Close examination with a loupe can show the dye in the veins of the stone as well as possible buildup of resin polymer.

Grade C Jade: bleached, dyed lavender

Grade A jade: natural lavender untreated

Evaluating lavender jade is based on color, clarity and cut. The carat weight being less important, but its translucency and texture become more of a consideration. (3 Cs + 2 Ts)

Color: hue (position on the color wheel), saturation (intensity of purple) and tone (lighter or darker purple), as well as the distribution of purple color throughout stone.

Color Wheel: Various hues of Jadeite

Clarity: imperfections that reduce the passage of light; Myanmar lavender jadeite include many different mineral inclusions of various colors (brown, black, green…); but most often in lavender jadeite is the amount of healed fractures that will affect the stones clarity.

Cut: Cabochons, beads and carvings are most popular; 7 Mohs Hardness makes the amount of detail in the carvings important.

Translucency: the amount of transparency in the stone: the best jadeite is semi-transparent, while opaque stones and cloudy patches reduce its value. Natural jadeite jade is polycrystalline so hardly transparent – we therefore use the term "translucency" only.

Texture: the degree of compactness due to very fine grain size; the finer the texture, the better the translucency and overall luster. Texture is often classified into three levels:

> **Fine:** "Old Mine"; indicating its texture, translucency and luster of highest quality due to its extremely fine grain size.
>
> **Medium:** "Relatively Old Mine"; medium grain size, acceptable translucency and luster.
>
> **Corse:** "New Mine"; roughest grain size, least translucency with lowest luster.

Materials and Method

Fifty five samples of cut (cabochons, beads, carvings) jadeite and jade imitations ranging from 3.4 to 194.2 grams were collected in Mae Sot, Bangkok, Grasse (France) and through internet (England, Italy and China). Standard gemological tests to distinguish jadeite from nephrite and other "jadeite" imitations include visual examination with 10X Loupe and Microscope, Refractive Index readings, Specific Gravity calculations, Short Wave and Long Wave Ultraviolet Radiation and UV-Vis NIR Spectrometer analysis.

The Raman or Infrared Spectrometer would give us the best analytical information, however this can only be done in a sophisticated laboratory and this proved too expensive for 55 samples. After contacting several laboratories, I had the incredible luck to be offered assistance by Mr. Jean-Marie Arlabosse. He has a lab equipped with a UV-Vis NIR Spectrometer, and over a 12 week period the samples were tested and their corresponding absorption trends analyzed. The spectroscope is helpful because both cut and rough jadeite can be tested, however in this case all 55 samples were close to opaque (beads and 7-14 mm thick carved samples) and finding a spectra proved difficult even with the thinnest lavender cabochons. (The spectroscope for instance is very helpful with thinner translucent green "Imperial jadeite" due to its chromium contents). The Chelsea Filter is helpful with identifying unstained chromium colored green jade which appears dull green (verses reddish for stained green jade). However with lavender colored jade, the results can be confusing due to coloring agents and resin impregnation levels.

From the fifty five samples:

34 from Bangkok and Mae Sot Thailand gem markets

16 from China through internet purchases

3 from Grasse (France) local jewelry markets

1 each from England and Italy

1) VISUEL EXAMINATION
   Each sample was cleaned, dried and examined closely using an 18mm-10X TRIPLET Loupe and a Gemoro Elite 1030PM Precision Microscope. Visual examination can help in the identification of mineral inclusions, dyes, resin impregnation, color stopping within the healed fractures and other characteristics special to lavender jadeite. Surface luster, fracture surface and texture are also important clues in distinguishing lavender jadeite.

Examination under a 10X Loupe and microscope

A full examination of lavender jadeite under magnification is necessary in order to help us identify its Grade, transparency and luster. Six key areas were used as benchmarks in order to best evaluate the Grade of jade:

1) **Surface Luster and reflectance**: look for a localized glassy surface luster with a vitreous reflection: A-jade fish pendant shows sharply defined reflections on the surface near his back and tail. The bottom of the A-jade eagle pendant shows a much higher brightness than other commercial B-jadeite (sample 49). These particular areas show a much brighter vitreous gloss than the lions, because the B-jadeite has a thick coat of polymer-impregnated resin that has been applied to fill in all the pores and cavities after the acid treatment. The result is less surface luster due to a lower refraction of the sealants.



Localized sharp reflection Glassy luster: A-jade Minimum surface luster: B-jade

2) **Surface color contrasts**: in A-Jade sections of strong cold color reflections can be observed as we turn the jade around in the sun. Even with translucent lavender jadeite, we can see a difference in the color of the reflections on the surface: A-jade shows strong cold color reflections which glisten as we turn them slowly. It's not the color difference, but the sharpness in the contrast, which separates A and B jadeite. Along the edge of the Buddha's stomach and chin we see clearly the distinctive pieces of this cold reflectance contrasting to the light reflectance from the sun. Again with the A-jade bead necklace, we

see distinct differences in reflectivity (not in the overall lavender color). Observing the B-jade, again their resin sealer reduces the amount of reflectance in their surface shine, so they are much less likely to exhibit this cold contrasted reflection.

A jadeite: Buddhas surface reflection

Types of Inclusions:

**Black and brown natural inclusions* are seen in Myanmar lavender jadeite. For example black oxide inclusions may include chromite or magnetite in the form of dots and speckles. These black oxide particles are usually present with the lavender jadeite's body colors which are developed by naturally incorporated transition metal ions such as manganese and iron. These may be imitated today and do exist in B and C jade – so we need to look carefully at its internal reflection. Within these jadeite pendants we observe black inclusions that reflects slightly – and is seen even better through the microscope. (Traces are left on the surface when the pendant was carved). This suggests A-jadeite with natural inclusions.

Natural black inclusions: tip of leaf on left and on plant base on right

**Colored weathering shell*: These are the intense color graduations used when carving to exploit the natural irregularity of jadeite. The weathering shell is oxidized on the outside by nature which produces a brownish color as in figure 1 below. This is a good indication of A-jade if we see very clear color boundaries AND have the impression that the coloring was done from the outside to inside of the piece. In this sample we see the brown oxidized edge that wraps around and encloses a lighter green base. This not only makes use of the color differences to create a scene of a brown river bottom with the fish swimming above

it in lighter green; but also indicates genuine A-Jadeite. Carving jade to achieve an attractive color contrast is referred to as “Qiao Se”, and usually is an indication of A-jade. This pendant in Figure 2 was deliberately carved using the “Qiao Se” technique to exploit the eggplants natural colors. The carver kept the lavender color exclusively within the eggplant part, while the leaves and stems were left in green and light green shades.

Figure 1: Colored weathering shell: A-jade

Figure 2: “Qiao se” carving technique

*_Cotton ball inclusions_*: These are snowball shaped inclusions that are actually isolated spheres of white cotton like fibers found most often in A-jadeite. When the round inclusion has clear boundaries, it is usually a good indication that the jade is naturel A-jadeite, because in B-jadeite, the white fiber boundaries are much more undefined and blurry. For example, on the grapes edge we see clearly defined cotton like inclusions, typical of A-jadeite; whereas with the lion pendant on the left, the cotton like spheres are much more uneven and blurry.

Blurry cotton balls: B-jade

Tiny well defined cotton balls on edges: A-jade

3) **Adularescence, glowing yellow effect:** in most A-jadeite we can observe a soft yellow glow when observing the piece against the sunlight. This is due to the refraction and diffraction (spreading of light) from the many crystal faces and fissures present in jade. For example, the lavender colored Buddha shows this yellowish glow along its side near the edges, which usually indicates A-jadeite. Even if the sample piece has poor translucency, in A-jade we could still see this adularescence (yellow glow) due to the evenly scattered light. Whereas with B-jadeite, the resin layer reduces its reflectivity and we see rather a white lavender tone as seen on the upper edge of the lion carving. The polymer resin that is applied to the B jade is usually what causes the blueish/lavender white glow instead of the warm yellow glow found in A-jade. Furthermore, the yellow

glowing internal reflection of the Buddha (adularescence) is a very important feature that help us to classify our lavender jadeite as A-jadeite because we do not see this internal feature in B or C jades.

A Jade: Adularescence yellow glow

B Jade: Bluish white glow

4) **Fissures**: These are essential in identifying A-jadeite:
*****Tiny white fissures: when we observe very white tiny fissures between crystals this usually indicate A-jade. One must confirm that the fissures are really whiter than the body color of the jade. B-jade does have fissures as well, but due to the impregnation of polymers, it is much harder to see and they do not appear so white from the surface.

White fissures

*****Color Roots: it is very important to examine *how* the color is spread within the jade; look for where the color stops. If the color stops at a fissure, this is a good indication of A-jade. Analyzing these boundaries where the color stops is therefore key in distinguishing A from B-jadeite. For example, in these A-jadeites we see the darker green color stopping at the fissure along the side of the eggplant as well as in different areas throughout this cabochon. In both samples, we can observe tiny white fissures that are whiter than its respective body color. B-jadeite and C-jadeite typically show color spreading regardless of the fissures and their boundaries.

Color roots: dark green color stops at fissures

***Color Drifting:** This is more commonly seen in B-jadeite and refers to this spreading of color within the grains and veins of the jade. Remember, in B-jade inside fissures are difficult to see, and on the surface after resin treatment what we observe are tiny veins under the surface– not white fissures lighter than the body color. The result is that the color is not blocked and we observe the color drifting as seen in this B-Jade lions pendant- the color drifts past the fissures and appears as tiny veins of blurry color along the surface. This is another technique we need to understand in order to classify lavender jade either A-jade or B-jade.

Color drifting

*Color Treated: this is different from natural jadeite "color drifting": this involves bleaching and then dying the jade with a purple color before coating with resin. Close examination with a loupe can show the dye in the veins of the stone as well as any buildup of resin polymer. In this sample, the 14K gold bracelet has dyed purple jade as we can see the color dye within the veins and small traces of purple color within the fissures. The color is much richer, but it can only be graded as C-jadeite due to its extensive treatment.


Color Treated: C-Jadeite

5) **The size and quality of carving** need to be examined: the smaller the piece the easier it is to impregnate with polymer and treated with dye than the larger pieces. Pieces smaller than 3-4 cm need special attention, as they are cut in mass production and easier to alternate. The quality of the piece should also be taken into consideration: Is the piece carved intricately on both sides with for example details of leaves all around and sharp underside carvings? Both lavender colored pendants below show these fine details and sharp pointy edges- a very good indication of A-jadeite. B-jade and C-jade are usually one-sided carvings with little or no deep carving lines and rounded edges as seen with the lion pendant on the far right. Remember, the acid treatment weakens the stones structure so it is harder to carve sharp details. Furthermore the back part of the pendant on the right is flat with no carving at all.

Intricate carving both sides

Backside of pendants: carved vs flat

2) SPECIFIC GRAVITY

Specific Gravity was determined hydrostatically for 37 samples; the other 18 were not possible due to their pendant hooks, clasps or strings. This was done at LGM (Marseille, France) with GEM-A's Hydrostatic Balance. The material was weighed first in air an then in water to determine the weight loss in water. The Specific Gravity was then calculated by dividing the materials weight in air by the loss of weight in water. Jadeites Specific Gravity is usually listed near 3.33 but it varies depending on impurities, air pockets and beeswax or resin coating.

The results are given on Appendix 1.

3) REFRACTIVE INDEX

Refractive Index is one of the most helpful instruments in the separation of jade from its simulants. Lavender jadeites RI is 1.66 which is much higher or much lower than its simulants. The difficulty I had in this case was finding a flat surface accessible to obtain a proper reading. A Refractometer with Monochromatic Light and RI fluid was used on all 55 samples. The majority of the samples needed to be read using the "distant vision" method in which I was obliged to hold just a corner of the jade carefully on the refractometer (with the RI fluid). This spot technique requires us to lift off the eyepiece magnifier until the stone appears as a tiny spot, with this I was more successful in obtaining a better reading. One needs to bob their head looking for the mid range between the light oval and the dark oval to estimate the midline halfway between the two. All but six samples tested had a RI of approximately 1.66; the others were in the 1.48 to 1.58 range – suggesting Calcite and Quartz material. Please refer to Appendix 1.

4) ULTRAVIOLET RADIATION

All 55 samples were viewed under Long-Wave and Short-Wave Ultraviolet Radiation to observe their florescence. This was accomplished at LGM using GEM-A's Ultraviolet Light Tester at SWUV 253 nm and LWUV at 365 nm. To study lavender jadeite

the gemologist first needs to determine whether the jadeite is treated or has naturel color. Lavender jadeite may be died by organic or inorganic coloring methods. Analyzing the fluorescence of lavender colored jadeite gives us important indications as to whether the color is natural, dyed and/or coated with resin polymers. A majority of samples showed a weak purplish-brown glow florescence to LWUV and Inert to SWUV (if not just a very dark brown glow). Some samples showed bright yellow glow in the SWUV and diverse colors in the LWUV. Please see Appendix 1 for details.

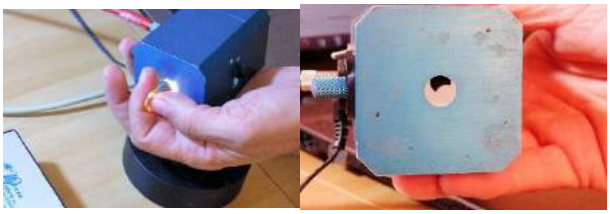
5) UV-Vis-NIR SPECTROMETER

The UV-Vis-NIR Spectrometer allows us to see characteristic absorption or emission positions along various ranges of energy by exposing the stone to visible and near visible light and seeing how it responds. The UV-Vis-NIR Spectra analysis can give us the best information (next to Raman Spectrometer) about whether the purple colored stone is natural, treated, and perhaps dyed. The emission and absorption features of lavender colored jadeite can be analyzed and compared to specific chromophore which can then provide us with interesting information on its color origin.

The 55 samples were tested for spectral reflectance using an UV-Vis-NIR Spectrometer: Ocean Optics USB4000 equipped with a halogen light source and an integration sphere. The sample holder is a *spectralon* with a concave holder. The signal is transferred from the integration sphere to the spectrometer through the optic fiber, and then the signal is transferred to the computer where the graph is produced using licensed Ocean Optic software. The spectral baseline was corrected by resetting the baseline back to 100% transmission before each analysis. Reflection is simply the fraction of light reflected from a surface as a function of wavelength. Measuring spectral reflectance seemed more adapted to the various sized samples, and allowed for more information on interpreting the spectrum curves and understanding their respective color origin. Under the guidance of Jean-Marie Arlabosse, an individual spectra was created for each sample noting key absorption bands and lines. The main absorption lines and curves for each sample are noted in Appendix 2.

Analyzing samples using Spectralon

Ocean Optics USB4000



Handheld samples at an angle: some samples so bright, that we needed to let some light out from the hole: this allows for the transmission amount to go back to 100%.

RESULTS

Gemological Data

The gemological data for each of the 55 samples that were collected are presented in Appendix 1. The color of the samples range from pinkish purple lavender to blueish purple lavender to light lavender green to light gray green. Five samples had larger color ranges showing dark brown to dark green and white areas. From these samples, RI values ranges from 1.48 to 1.67. In samples 8, 9, 17, 20, 21, 22 and 43 two or more spectrums were completed in order to analyze the different colored areas within the same sample number. The SG of our samples were between 2.51 and 3.36, noting that 18 samples were unable to be weighed properly due to strings, clasps or mountings in gold. The variations in these SG values may be explained by the mineral composition and the presence of impurities and impregnated polymers. The diffraction spectroscope was used but the readings proved difficult to see especially with the lighter colored lavender jade beads. In some of the thinner cabochon jades we see an absorption line in the blue area, typical for Iron Fe. LWUV showed a varied florescence ranging from dark purple, or glowing pink to deep reddish brown. Several samples reacted to the SWUV, and when they did it was extremely faint reddish brown, except in a few polymer coated samples that had brighter glowing spots. The Chelsea filter is helpful with green jadeite, but with the lavender jadeite, most samples just showed a faint pinkish or gray green color. The exception to the sample lot was the gold dyed purple bracelet which was bright pink under the filter. Both the CCF and handheld spectroscope data were not included in this report, except to mention these exceptions.

Each sample piece was measured by reflectance with a UV-Vis NIR spectrometer and their significant absorption lines recorded. The samples were separated into five main groups by their similarity in absorption spectrum:

Group 1: 437 nm and 636/658/691 nm Chromium jadeite

Samples: 1,3,20b,22b,43,44,48,50.

Group 2: 437m and 580 nm Manganese jadeite

Samples: 2,5,9,14,15,16,18,20,23,28, 29,30,32,33,35,41,42,46,47,49,54.

Group 3: 437 nm and 630 or 650 or 670 nm Iron jadeite

Samples: 6,7,10,11,12,13,17a,19,19a,21b, 22a,22c,38.

Group 4: 437 nm and 550/630 nm "Shouldered" jadeite

Samples: 4,8a,8b,17b,21c,24,25,26,27,31, 34,36,37,53,55.

Group 5: other spectrum: 2 Brown jadeite, 1 dyed, 5 simulants

Samples: 20a,21a,22,39,40,45,52.

Gemological properties and color origins of jadeite have been researched and documented by several authors to date (Rossman (1974), Koivula (1982), Nassau (198), and Lu (2012). Interpreting the spectrometer curves allow us to match the features with these researched color origins to create the 4 main categories of jadeite and the last category to include the non-lavender jadeites and the confirmed treated and dyed jade. Please see Appendix 2 which includes the spectrum and photo of each sample.

Microscopic Examination

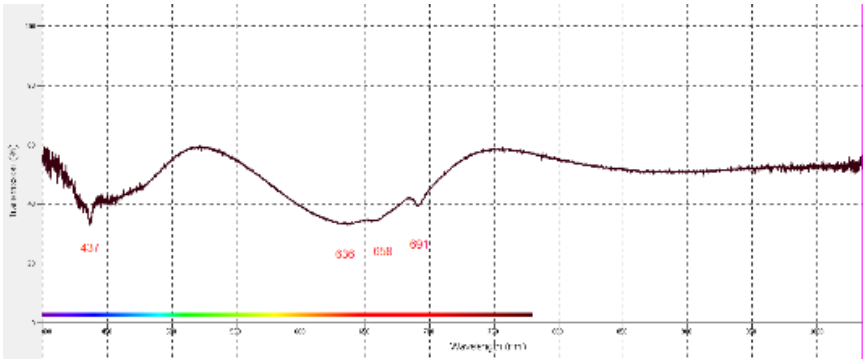
Microscopic examination was necessary allowing us to visually identify the quality of the luster and surface reflection. Most samples in Group 1, 2, 3 and 4 showed a fine bright surface luster with defined reflective shadows. Some of these samples even showed a cooler color in the reflective shadow while still having a warm glowing body color. In addition, several samples exhibited intricate carving techniques and possessed sharp corners and two sided carving details. Fine white fissures were present at most surfaces, and the color boundaries were clearly defined at the fissures. Crystal growth direction could be seen and several pieces had brown to light brown inclusions. On some of the smaller thinner samples, small white cotton ball inclusions could be seen. Also on three samples weathering shell techniques were used to maximize the variations in the jades coloring ranges present in the original rough.

Samples in Group 5 showed much less surface luster and reflectivity due to the polymer coating and in certain cases evidence of dying. We also have a harder time distinguishing the fissures and the adularescence as the transparency was more blurry. Inclusions were not apparent, and only in one sample could we see blurry edges with white inclusions (sample 40) In the majority of pieces, there seems no color boundaries, they possessed the color drifting where the color spreads throughout regardless of where the fissure stop. Most were thinner and not carved in detail. Two samples exhibits color dye in the cracks and veins, again very hard to see the crystal structure (samples 39 and 52). In addition, samples 22, 39 and 40 tested different for their SG, RI and SWUV than

the other jadeite samples, so although they were announced and resembled lavender jadeite, their properties proved not to be jade.

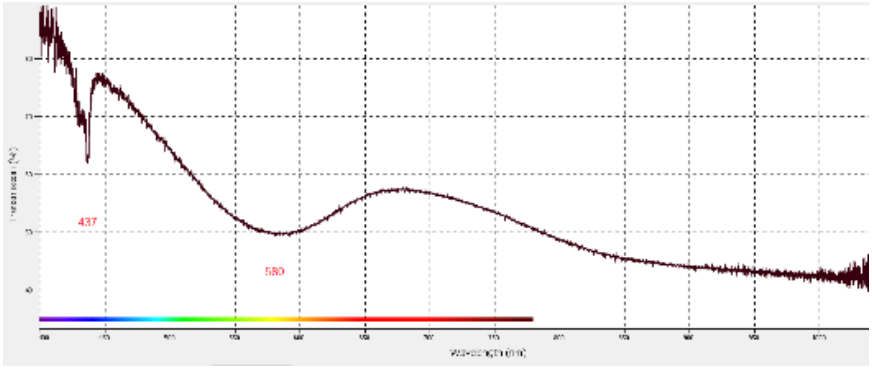
UV-Vis NIR Spectrometer: Reflectance Spectrum

Group 1:



The first group of samples consists of naturel jadeite colored by Chromium. The peak at 437 nm for Fe3+ is present along with 3 bands in the red to orange part of the spectrum near 630, 660 and 691 nm. When we observe the 691 nm peak, with or without all 3 lines, this indicates a material colored by chromium. In this case, **eight samples** are chromium colored and if transparent enough may be considered as “Imperial Jade” for this reason. Lighter green jadeite colored by chrome may or may not show all three bands depending on the deepness of chrome in the sample.

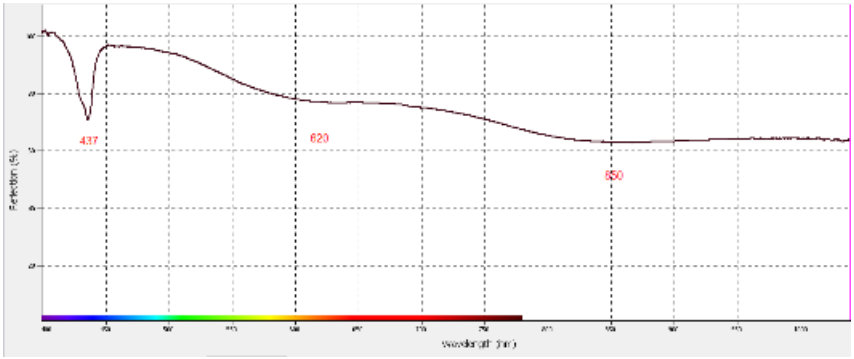
Group 2:



In the second group, the spectrometer showed a defined peak at 437 nm for Fe3+ plus a broad absorption band in the 580 nm range. This is a typical spectra for natural Burmese lavender jadeite colored by Manganese. Burmese jadeite only has small amounts of iron but does have enough manganese to provide a lavender hue. In lavender jade the Mn3+

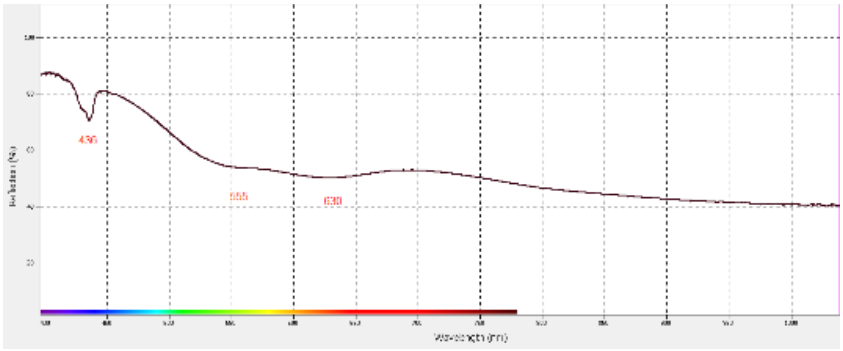
is ionic charged and matches those of Al3+ and in this case, the Mn can substitute the Al giving the jade its color. **Twenty one samples** fall into this group, and their respective reflectance measurements are very similar.

Group 3:



This group included reflectance spectrums with 437 nm and another peak between 620 and 670 nm. **Eleven samples** were put into this group because although they tested jade, their reflectance measurement were not strong enough with specific bands to conclude color origin. Most had a hue of green to gray green. The spectrometer is very helpful when we observe bands and lines, but these eleven just showed a sort of continuum which proved to be difficult to analyze. We need to bring this group of samples to a bigger laboratory for more conclusive testing.

Group 4:



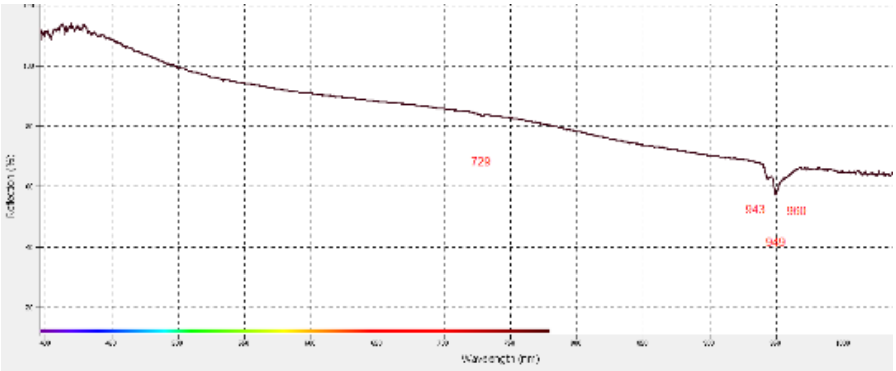
Group 4: Spectrums “shouldered” between 550 and 620

Group 4 includes **fourteen samples** of jadeite that show the 437 nm peak along with double broad bands (“shouldering”) of absorption between 550 and 620 nm. The 437 nm we recognize as iron (typical jadeite), but the “shouldering” absorption bands need to be examined more closely. At first, according to previous data, we may interpret all these samples as treated lavender jadeite. Treated lavender jadeite according to Ren Lu has

these double absorption bands between 550 and 620 suggesting that the concentration of manganese is too low, and the introduction of a dye is done to improve color. The dye broad bands are superimposed with the manganese band to produce these spectrums as seen with our sample number 52: the gold and dyed bracelet. Evidence of purple dye in sample 52 can be seen in the veins with or without a microscope. In Group 4 no evidence of dye was seen in any sample, even with the loupe and microscope. Several of these sample exhibited a bluish purple hue – rather than the pinkish purple hue in Group 2. These samples were subsequently tested in Bangkok in February 2016 at the GIL Laboratory and all were determined to be natural jadeite with no evidence of any treatment.

The fact that these were exclusively purchased in February 2015 at Mae Sots border, made me feel that further investigation was in order because how can half the samples bought there test naturel lavender Manganese colored and the other half be naturel with a different coloring origin? Seven samples exhibit a slightly bluer hue than those in Group 2, and may be considered to be a blueish lavender jadeite rather than a pinkish lavender jade. Otherwise all other gemological testing methods show they are practically identical to the Manganese Group 2: same RI, SG, LWUV and SWUV, and especially under the microscope. Further research on these bands may show another reason for their color origin differences and hence spectrum. For consideration during my research I thought it interesting to note: Ren Lu's article mentions a Bluish Jade from Japan which is colored differently from the Burmese jade: it contains Iron and Titanium as the coloring elements. In addition according to Harlow and Sorenens article Blue jadeite from the Otoigawa area in Japan owes its coloring to Titanium amounts, and although not yet studied, they suggest it results from the intervalence charge transfer with Fe as in sapphire. This group of samples all with the same absorption trends merit further investigation before concluding. A possibility of sacrificing a sample for chemical testing may be helpful in determining their unique chemical combination.

Group 5:



This group includes 8 samples of which 3 are jadeite and 5 are simulants. Five were identified as non-jadeite after gemological testing methods such as RI, SG and the microscope. Their different spectral absorption positions across the range of radiation energy provided further information about their origin. There was no peak near 437 nm, and the result suggests material such as nephrite, dyed quartz, calcite and white quartz. These samples have been included in this study to show what imitations can be found in the market listed as “natural lavender jade” and to present their differences in color origin to the other natural jadeite samples in this study.

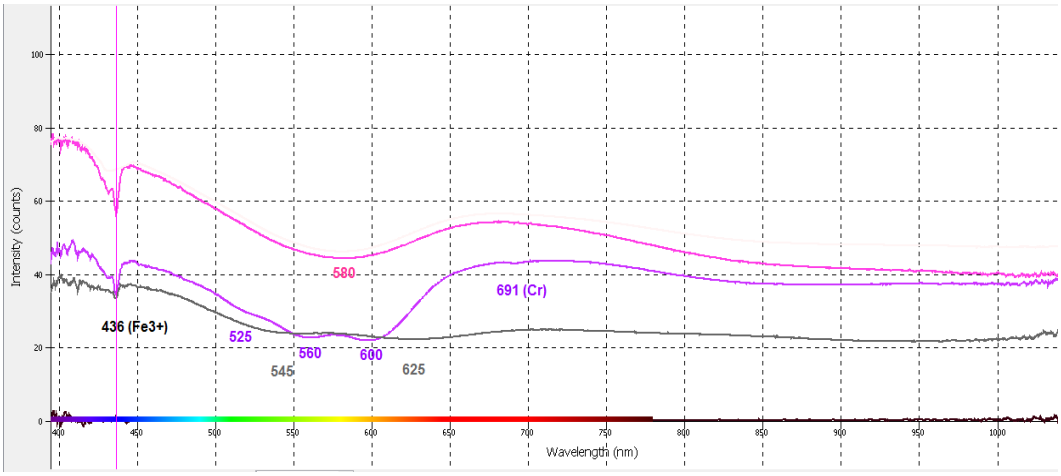
SPECTRUM COMPARATIVE:

This UV-Vis-NIR spectra combines three different specimens of jade that are all considered to be lavender jade, but have distinctly different spectrums. Each stone has produced different absorption characteristics: all three pieces show the 437 nm peak – typical of natural jade. The first piece (pink line) is natural Burmese lavender jade. The absorption near 580 nm is attributed to manganese: the Mn3+ concentration. The second piece (purple line), although jade, has been treated with an unknown coloring element: the loupe, the microscope and the UV florescence has confirmed a definite color treatment has been applied. Its spectra shows a "shouldering" or multiple broad bands between 525 nm and 600 nm. The broad bands from the dye are combined together on the spectrum with the insufficient manganese present to give this typical absorption near 580. The third spectra (black line) shows a similar spectra to the dyed sample above: it has two bands of absorption between 545 nm and 625 nm but its Fe2+ peak is much smaller: this may be due to the darkness in the color of the sample or the lack of Iron in the ion structure. This is naturally colored and has no evidence of treatment: however the color origin is not manganese and needs to be determined.


GROUP 2: Natural Burmese Lavender Jade (Manganese)


GROUP 5: Treated Lavender Jade (C-jade added colorant)


GROUP 4: Natural Lavender (bluish) Jade (Iron? Titanium?)



UV-Vis-NIR spectra of jadeite samples; (a) lavender natural, manganese colored, (b) lavender treated: bleached + impregnated purple and (c) lavender natural unknown color origin.

CONCLUSION

It is very complex to identify lavender A-jadeite with just a loupe and testing the SG, RI and UV information. My study suggests that we need at least a combination of gemological techniques and specific spectrometer analysis to help distinguish natural lavender A-jade from the other jadeites and treated jade. The use of the UV-Vis-NIR helps to measure and understand the characteristic absorption patterns of variously colored jade. Different color origins have been established in the past by several authors, but only half of my Thailand sample pieces can be explained applying their research. Raman Spectroscopy is one of the best techniques, especially in identifying resins used and in providing information on geographical origins. FTIR analysis is another technique that uses infrared to measure absorption in jade. Absorption is caused by the vibrations in jade's molecular structure. These sophisticated methods are safe to test on the jade however quite pricey and not possible to carry into the field. The Ocean Optics Spectrometer does have a smaller transportable version, and may be key in the future for gemologists who need such precision. Even with all this equipment, certain sample groups still need to be examined further before concluding on their color origin.

In this study, I included lavender jade samples purchased through the internet from China in order to investigate their color origins and to understand what is being offered on the international market and at what price. To my surprise, several inexpensive pieces from China (samples 2,5,9,35,46,47,53 and 54) were in fact Manganese colored naturel lavender A-jadeite. On the other hand, two pieces purchased on the Myanmar border in the town of Mae Sot turned out to be very impressive simulants (sample 22 and 40). We all know how emeralds are oiled and put back into the mines for naive tourists, but these lavender jade pieces in group 4 all tested to be natural jadeite, but included half unknown color origin and half manganese origin with very little difference regarding the other gemological properties. My conclusion suggests that with group 4, perhaps they never came from Burma- perhaps they have come from further away (Japan blue jade? Ren Lu's article) and found their way into the Mae Sot Market amongst the other jade… It may also be possible that maybe there is something else that happened with the iron during the last stages of crystallization in a certain vein along the Jade Tract in Burma that has yet to be analyzed and reported…

BIBLIOGRAPHY

Franz, Leander, et al, “A Comparative Study of Jadeite, Omphacite and Kosmochlor Jades from Myanmar, and Suggestions for a Practical Nomenclature”, The Journal of Gemology, 34(3), 2014, pp. 210-229.

Gem-A, The Gemological Association of Great Britain, “The Diploma in Gemology Course”; 21 Ely Place, London, 2009.

Hargett, David, “Jadeite of Guatemala: a Contemporary View”; Gems and Gemology, Summer 1990, pp. 134-141.

Harlow, G. E. and Sorensen, S. S. “Jade: Occurance and Metasomatic Origin”; American Museum of Natural History, New York, N.Y.

Hobbs, Jill M., “The Jade Enigma”, Gems and Gemology, Spring 1982, pp. 3-19.

Hughes, Richard W. et al, “Burmese Jade: The Inscrutable Gem”, Gems and Gemology, Spring 2000, pp. 2-25.

Jianjun, Li et al, “Visually Distinguishing A-jadeite from B-jadeite”, The Journal of Gemology, 2008, Volume 31, No. 3/4, pp. 125-131.

Koivula, John I, “Some Observations on the Treatment of Lavender Jadeite”, Gems and Gemology Spring 1982; pp. 32-35.

Lu, Ren, “Color Origin of Lavender Jadeite: An Alternative Approach”, Gems and Gemology, Winter 2012, pp. 273-283.

Morishita, T., et al. “Trace element compositions of jadeite (+omphacite) in jadeites from the Itoigawa-Ohmi district, Japan: Implications for fluid processes in subduction zones”; Island Arc, 2007, 16, 40-56.

Nassau, Kurt and Shigley, James E. “A Study of the General Electric Synthetic Jadeite”, Gems and Gemology Spring 1987; pp. 27-35.

Rossman, George R., “Lavender Jade. The Optical Spectrum of Fe3+ and Fe2+ to Fe3+.” Intervalence Charge Transfer in Jadeite from Burma”, American Mineralogist, Volume 59, 1974, pp. 868-870.

www.slideshare.net/mobile/aung3/myanmar-cco-pmetadatapresentation-13032012 , pp. 1-10.

www.wisegeek.com/what-is-a-chromophore.htm

www.boundless.com Silicate Units, Silicate Chains, Silicate Sheets: Chemistry, Concept Version 8.

Zara, Louis, “Jade”, 1969, Published by iUniverse.com, Inc., Lincoln, NE, USA; pp. 25-45.

ACKNOWLEDGEMENTS

A special thanks to **Jean-Marie Arlabosse**, Chemist, Research and Development at Galderma Laboratories, who gave me access to his UV-Vis NIR Spectrometer and helped with the various interpretations for these numerous samples. His guidance over several months as well as translating complicated informations from French to English has been extremely generous.

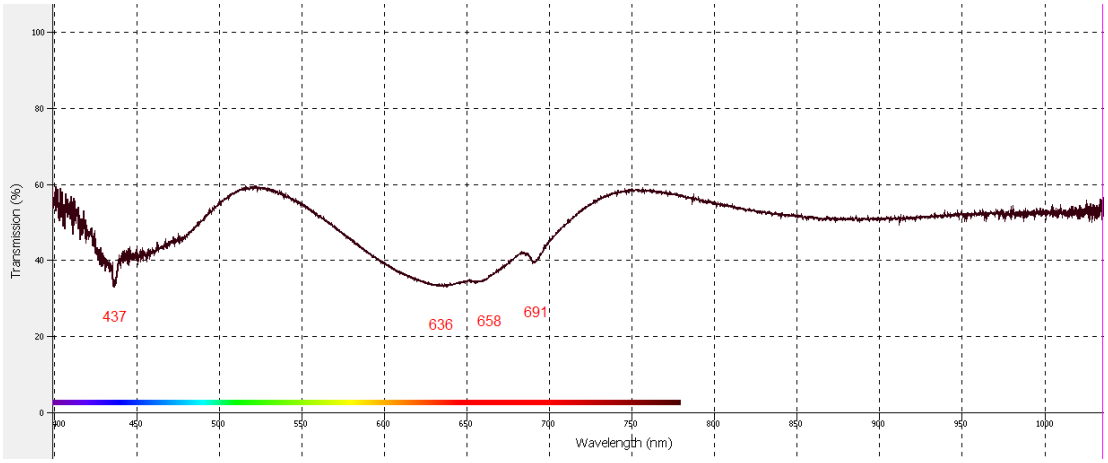
I would also like to thank **Jean-Claude Frediani**, Gemologue and Jewelery Business Owner in Nice, France. He graciously took the time to help me achieve detailed pictures of jade. In addition, he shared his expert knowledge and experience in examining the different colors and qualities of Burmese jade.

Sample No.	Description	Provenance	Carat	SG	RI	SWUV	LWUV	Spectrometer
1	Green rabbit	Grasse	32.921	3.116	1.65	Inert	chalky blue glow	437 line; 636,658,691 absorption Chrome
2	lavd Buddha	China	46.233	3.32	1.66	faint brown glow	purple glow	437, 580 broad absorption Mn
3	lavd green fish	China	10.945	3.3	1.65	deep red brown	purple glow	437, 545,635,691 absorption Fe Cr
4	Pair cab deep purple	Mae Sot, TH	40.805	3.34	1.66	Inert	Inert	437, 545,625-shoulder
5	Pair leaves	China	30.587	3.3	1.66	dark brownish	deep purple glow	436, 580 broad absorption Mn
6	Bracelet beads (15) green	Grasse	22.373	3.189	1.66	slight chalky blue	chalky blue glow	437, 800,960
7	Pair Lotus flowers green lavd	China	47.371	3.31	1.66	Inert	bluish glow	437, 600, 850
8	Pendant: large fish w/ purple ball	Mae Sot, TH	172.8	3.19	1.66	dark brownish	purple glow	purpleball: 437,550,635/ gray: 437,635,850
9	Pendant: lions on flower	China	89.376	3.33	1.66	Inert	4 spots purple, rest dark	purple: 437,580 green: 437, 580
10	Necklace green beads, gold clasp	Mae Sot, TH	495 ct est	N/A	1.66	Inert	pinkish glow	437, 620, 850
11	Necklace, white beads unstrung	Mae Sot, TH	4.666/bd	3.2	1.63	Inert	some glow, some dark	437, 630
12	Necklace, green graduated beads, 40 cm	Mae Sot, TH	511 ct est	N/A	1.66	Dark orange-red	orange-brownish	437, 650
13	Necklace, light green graduated, 53 beads	Mae Sot, TH	468 ct est	N/A	1.65	light gray/orange	very glowy white	437, 610, 875
14	Necklace 66 med size green-lavd beads	Mae Sot, TH	9.054/bd	3.2	1.66	Inert	some glow some don't	437, 585, 880
15	Necklace 47 graduated lavd	Mae Sot, TH	506 ct est	N/A	1.66	weak brown glow	reddish purple	437, 590,
16	Necklace 50 graduated lavd	Mae Sot, TH	376 ct est	N/A	1.66	weak brown glow	reddish purple	437, 580
17	Sautoir green and white midsize 114 beads	Mae Sot, TH	970 ct est	N/A	1.66 1.66	inert	some glow, some don't	green: 437, 625, 900/ white: 437, 550, 625
18	Pendant lavendre goddess	Mae Sot, TH	151.655	N/A		weak red brown	pink deep glow	437, 580
19	Necklace double small green beads	Mae Sot, TH	303 ct est	N/A	1.64	Dark orange-red	low faint brown	437, and 437, 600

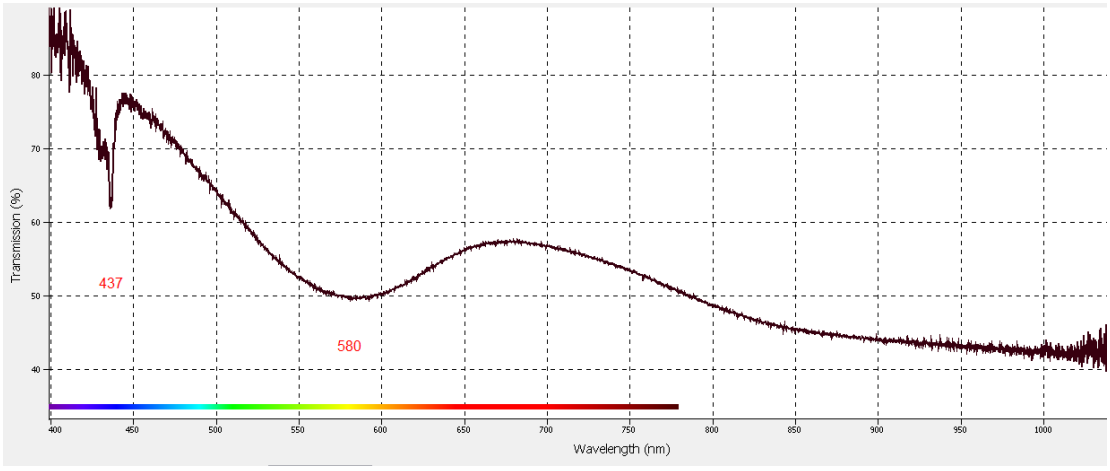
Sample No.	Description	Provenance	Carat	SG	RI	SWUV	LWUV	Spectrometer
20	Necklace triple small green,brown beads	Mae Sot, TH	383 ct est	N/A	1.66	Dark orange-red	light green mixed	437, 485, 900/ 437,635,680,691/ 437, 585,870/437,600
21	Necklace lavd small beads	Mae Sot, TH	182 ct est	N/A	1.66	reddish orange	red-pink white chalky	480, 900/437, 620, 850/437,550,620
22	Bracelet 20 green white beads	Mae Sot, TH	159 ct est	N/A	1.48 1.65	less glowy	yellow,white brown	436,870/436,630,655,691, 870/436/ no bands lines
23	cab 1 lavd	Mae Sot, TH	3.432	3.328	1.66	Inert	deep purple brown	436, 525
24	cab 2 lavd	Mae Sot, TH	10.22	3.33	1.66	inert	pinkish glow	436, 555, 630 shoulder
25	cab 3 lavd	Mae Sot, TH	4.059	3.33	1.67	Inert	chalky white glow	437,550, 620 shoulder
26	cab 4 lavd	Mae Sot, TH	10.799	3.319	1.665	Inert	purple glow	437, 550, 620 shoulder
27	cab 5 lavd	Mae Sot, TH	9.695	3.328	1.66	inert	yellow-pinkish	437, 550, 625 shoulder
28	cab 6 lavd	Mae Sot, TH	12.827	3.315	1.67	weak brown glow	purple glow	436, 580
29	cab 7 lavd	Mae Sot, TH	11.84	3.291	1.66	weak brown	deep purple glow	436, 580
30	big cab 8 darker lavd	Bankok, TH	48.193	3.305	1.66	Inert	dark orange purple	437, 580
31	big cab 9 lavd greem spots	Bankok, TH	36.606	3.32	1.65	inert	purple glow	436, 550, 650 shoulder
32	big cab 10 light and dark lavd	Bankok, TH	42.254	3.33	1.65	inert	purple glow	436, 580
33	big cab 11 lavd, green bottom	Bankok, TH	42.27	3.317	1.66	Inert	pinkish purple	436, 575
34	cabs pair 1 lavd	Mae Sot, TH	23.964	3.226	1.66	Inert	pinkish	436, 550, 625 shoulder
35	Necklace 13mm beads, whitish-light lavd	China	1336 est	N/A	1.66	Inert	pinkish	437, 580
36	cabs pair 3 lavd	Mae Sot, TH	14.374	3.328	1.66	inert	pinkish	435, 550, 620 shoulder
37	cabs pair 4 lavd	Mae Sot, TH	18.768	3.229	1.66	Inert	one glows more(thicker)	436, 550, 620 shoulder
38	bracelet 14 beads 13 discs green spotty	Grasse	338 ct est	N/A	1.65	Inert	partial glow	436, 650, 825
39	"purple jade" ebay beads	England	6.964	2.518	1.54	reddish brown	reddish brown	550, 580, absorption yellow
40	purple bangle	Mae Sot, TH	291.55	2.689	1.48-50	yellow glow	white spotty glowing	729, 943, 949, (main peak) 960
41	Eagle pendant lavd	Mae Sot, TH	93.057	3.27		deep red brown	darker red glow	437, 580
42	Eggplant pendant lavd	Mae Sot, TH	58.006	3.134	1.66	weak red brown	darker pink glow	436, 585

Sample No.	Description	Provenance	Carat	SG	RI	SWUV	LWUV	Spectrometer
43	Fish pendant 3 circles: green, brown edge	Mae Sot, TH	88.69	3.167		Inert	deep red brown	white lavender: 436, 600, 692/green:436,640,660,691
44	green swords pendants	China	21.7	3.328	1.65	Inert	darker pink glow	436, 640, 660, 691 Cr
45	Flower pendant green	China	27.512	3.26	1.66	Inert	purplish	470, 625, 680, 940
46	Fish kissing	China	311.05	3.265	1.66	weak brown glow	deep purple glow	436, 585, 900
47	Bracelet beads green string	China	321 ct est	N/A	1.66	inert	deep purple rose	436, 585
48	16 Barrel beads green	China	3.292/bd	2.895	1.64	inert	some glow some don't	437, 640, 660, 692, 850
49	Pendant grape	China	33.45	3.33	1.66	weaker red brown	darker redish glow	436, 580
50	Green lotus certified	China	29.01	3.33	1.66	weak brown glow	darker brownish glow	436, 630, 692, 860
51	Ring gold jade cab	Mae Sot, TH	3 ct est	N/A	1.66	inert	dark red brown glow	
52	Purple jade gold bracelet	Italy		N/A	1.65	redish glow	pink red orange glow	436, 520, 560, 600
53	Necklace 44 big beads	China	851 ct est	N/A	1.65	some white spots	dark brown red glow	436, 560, 625
54	Necklace barrel beads lavd	China	234 ct est	N/A	1.66	weak brown	darker red brown glow	437, 580
55	Lion on clouds	China	53.05	3.256	1.66	inert, white specs	darker purple glow	436, 550, 640, 800

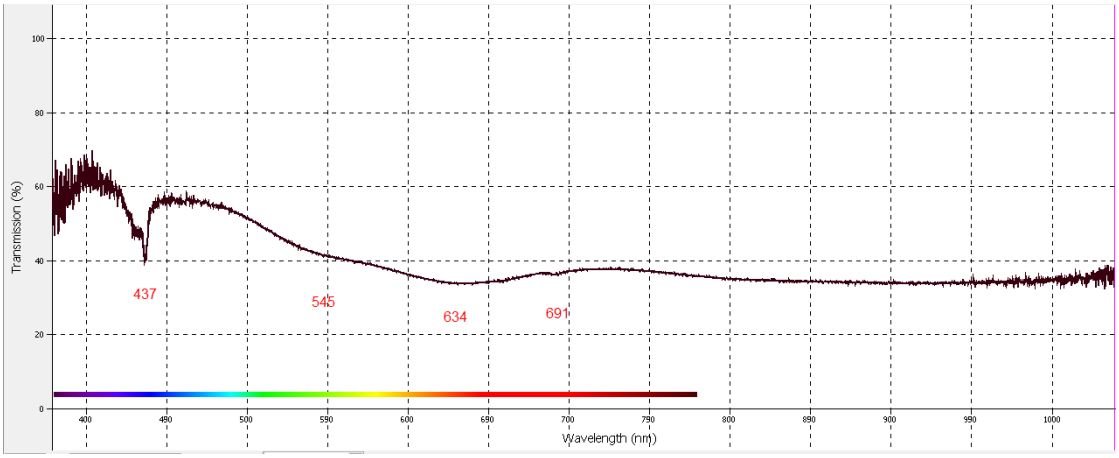
1: rabbit



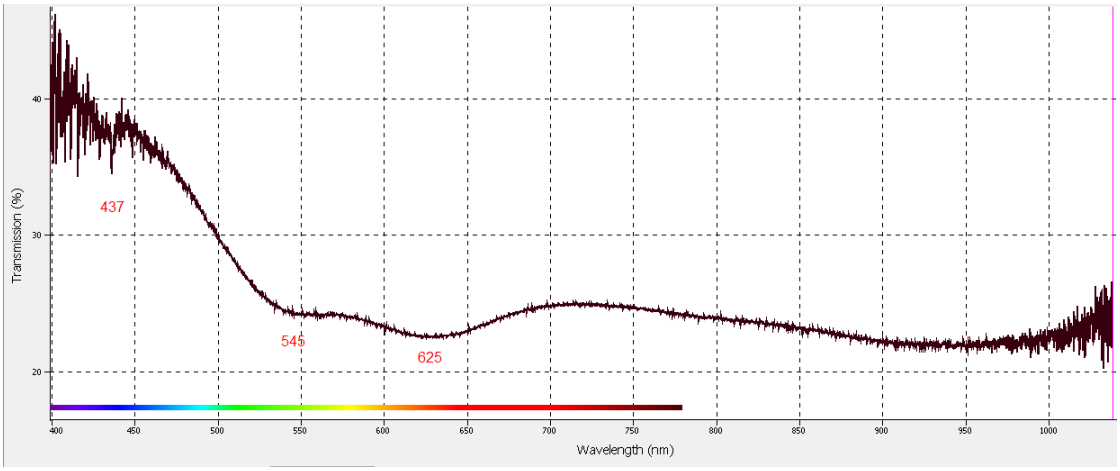
2: buddha



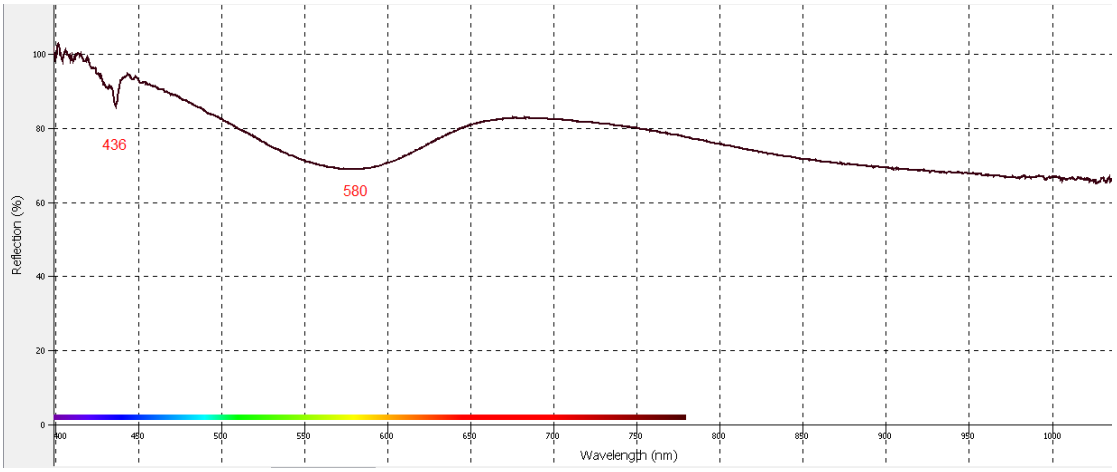
3: fish



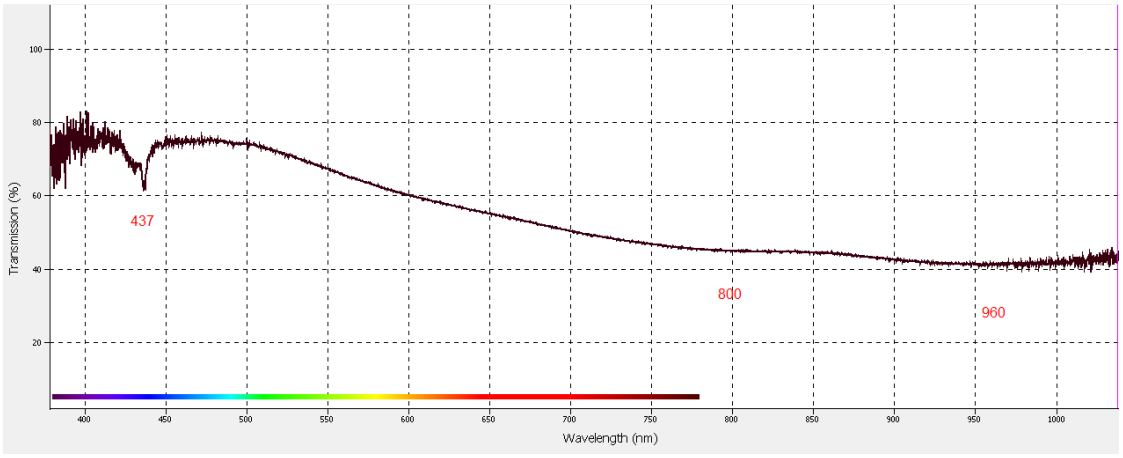
4: pair cabochons dark purple



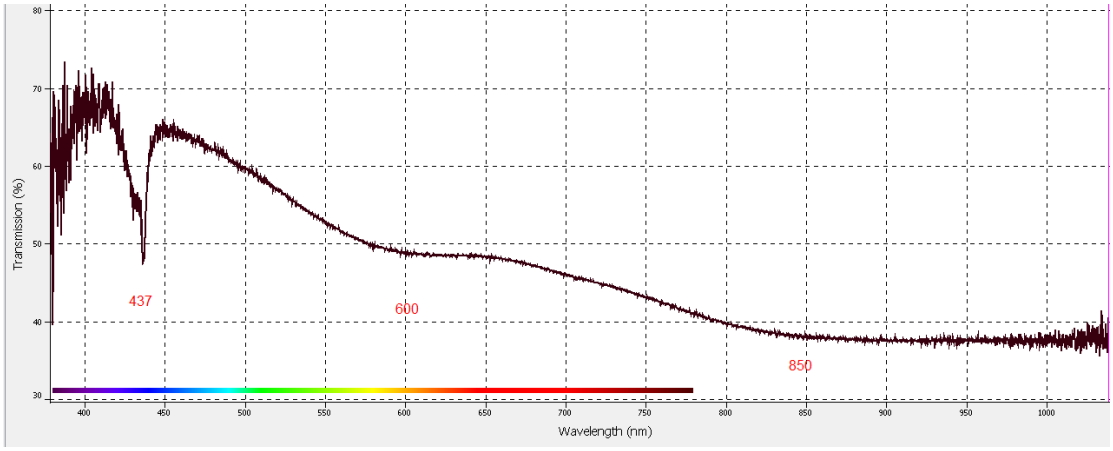
5 lavender leaves (pair)



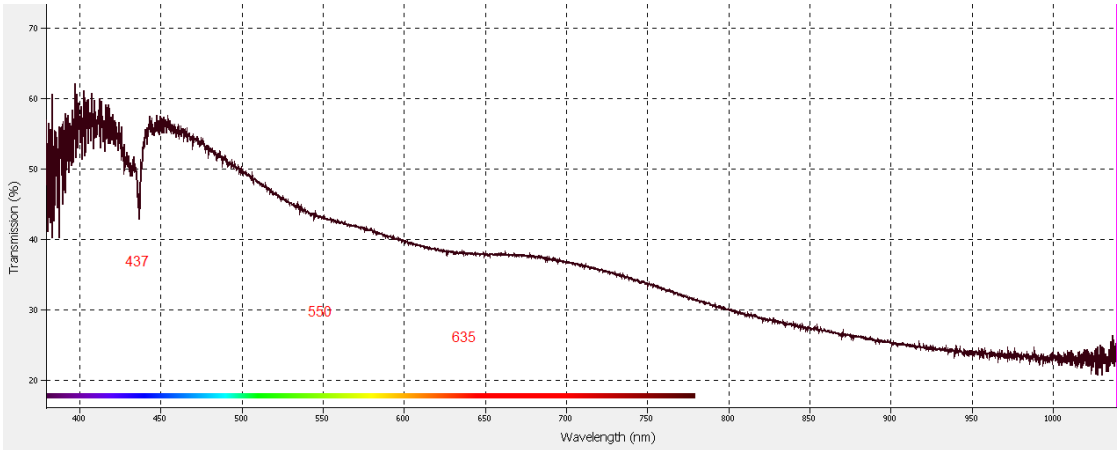
6: green bracelet



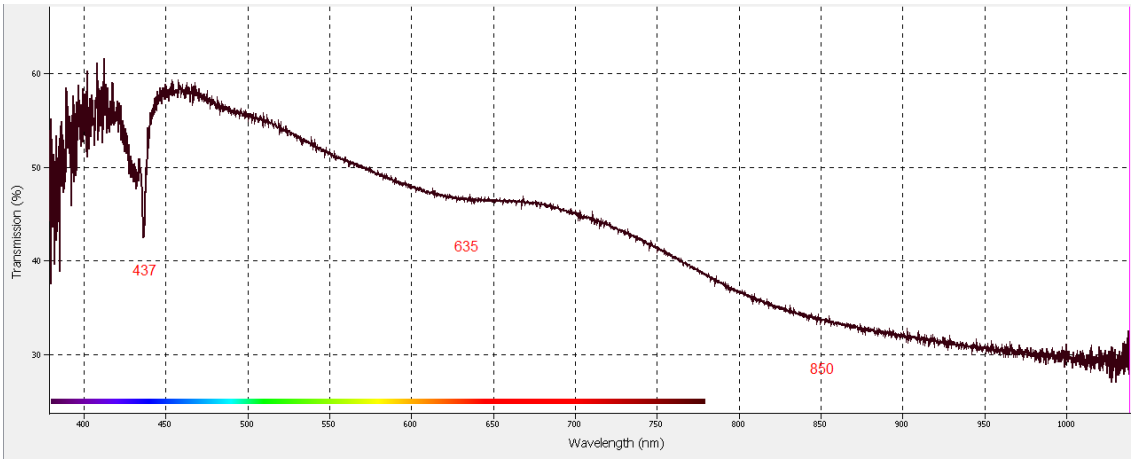
7: lavender green lotus flower (pair)



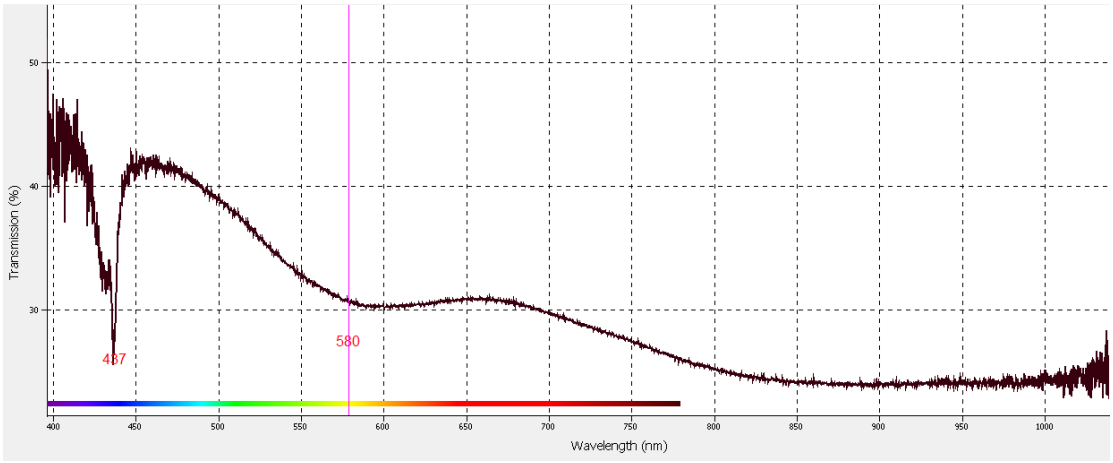
8a: fish pendant: purple ball part



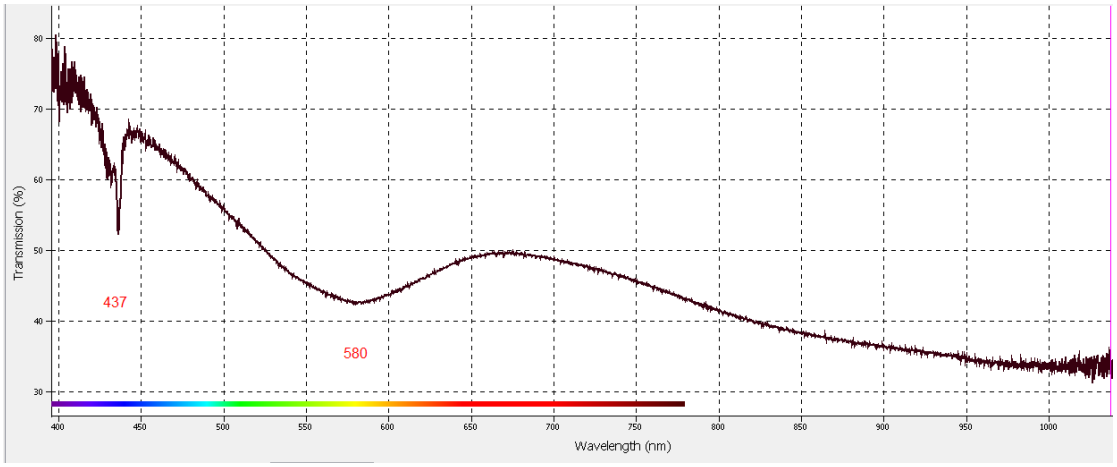
8b: fish pendant: light purple-gray fish



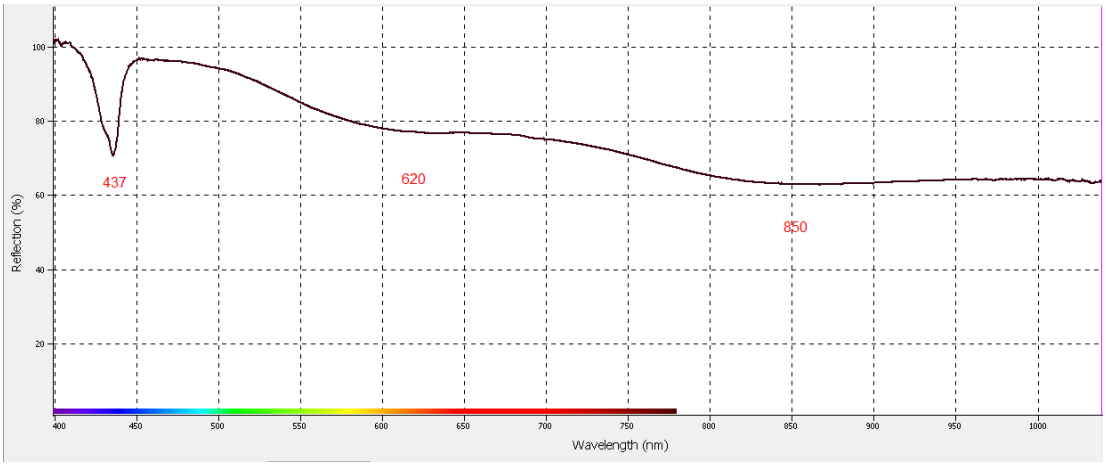
9a: lions: lavender part



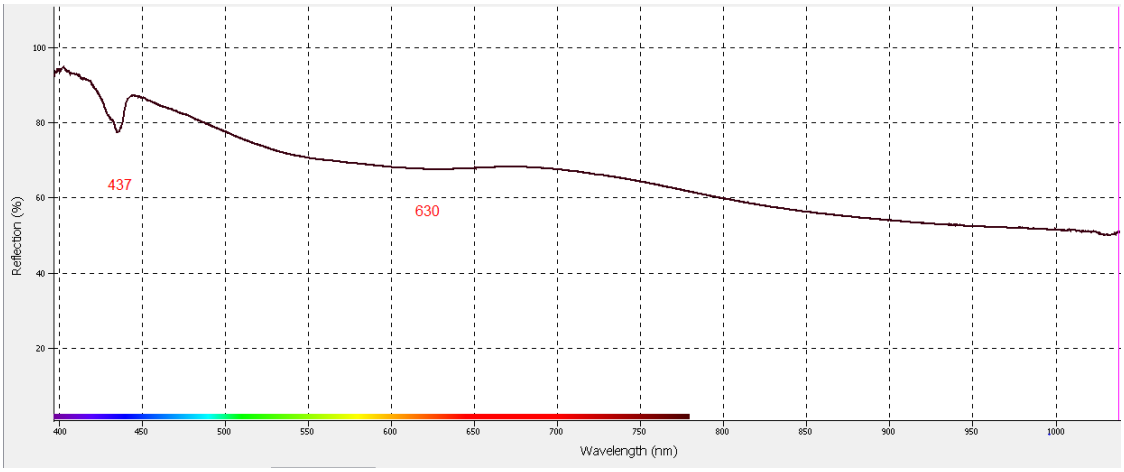
9b: lions green part



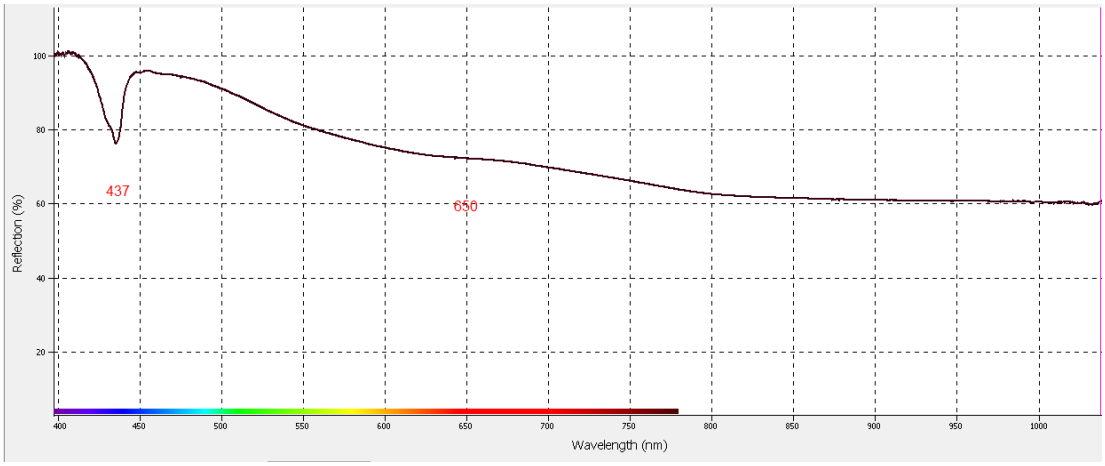
10: necklace green beads gold clasp



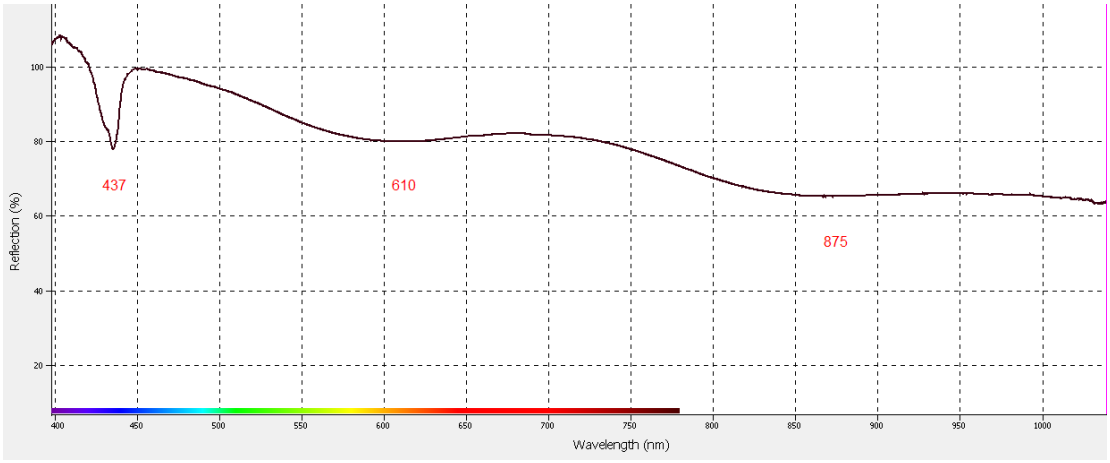
11: necklace white beads



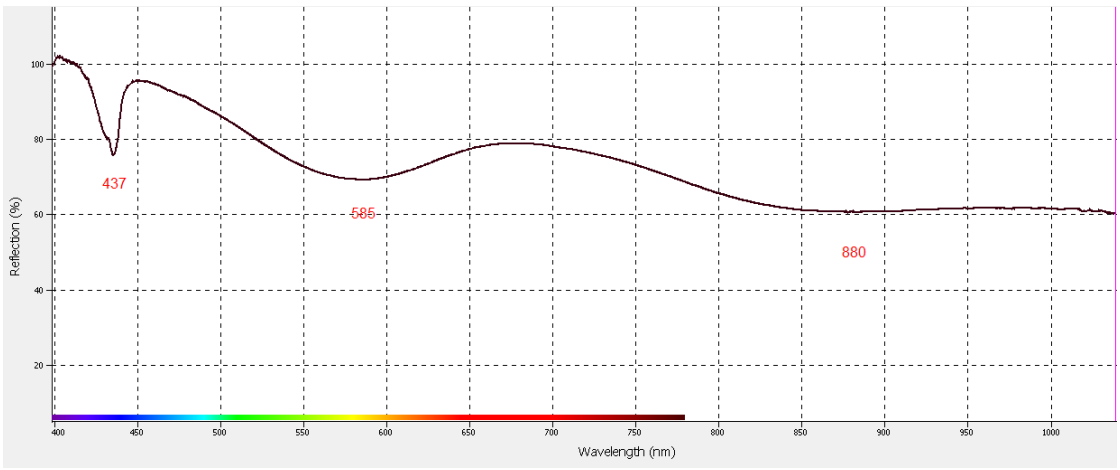
12: necklace green graduated



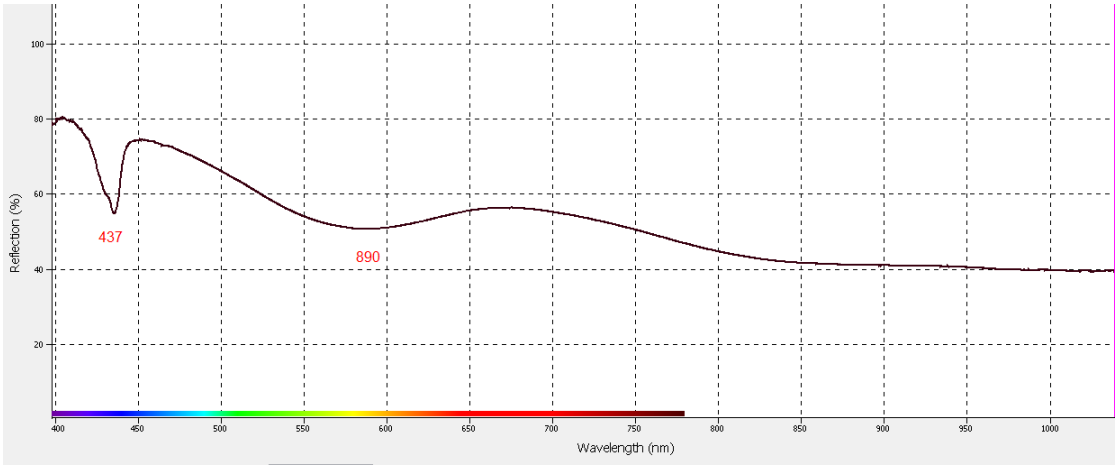
13: necklace light green graduated



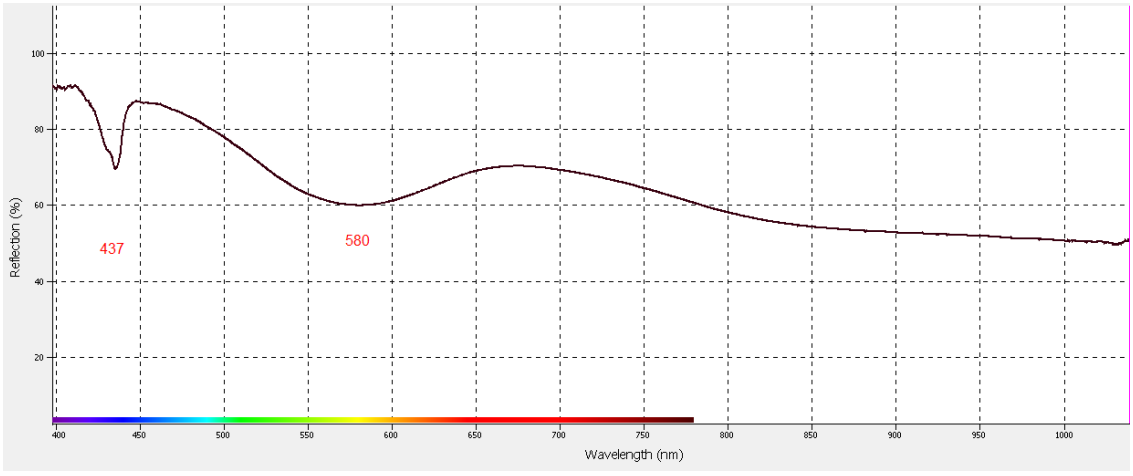
14: necklace med size green-lavender beads



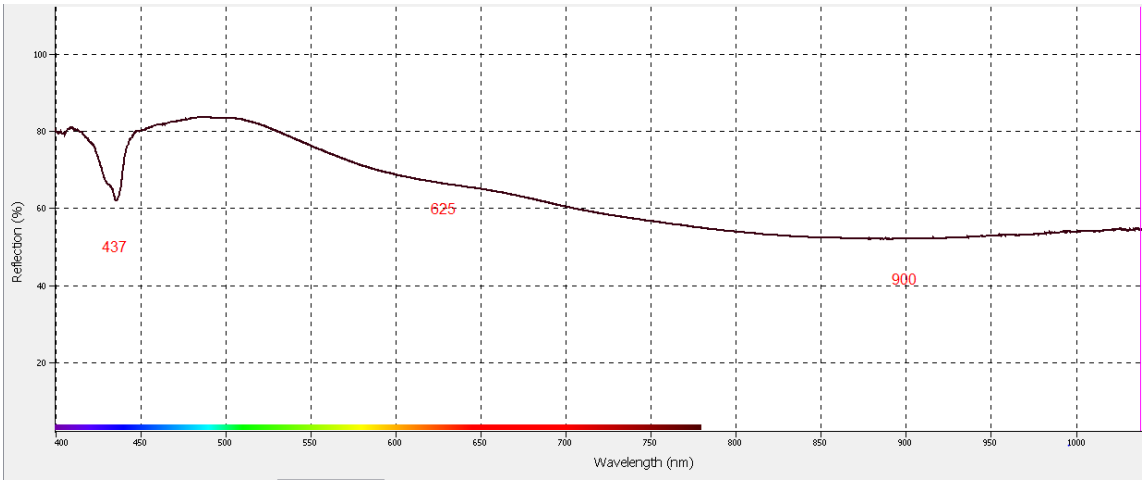
15: necklace 47 graduated lavender



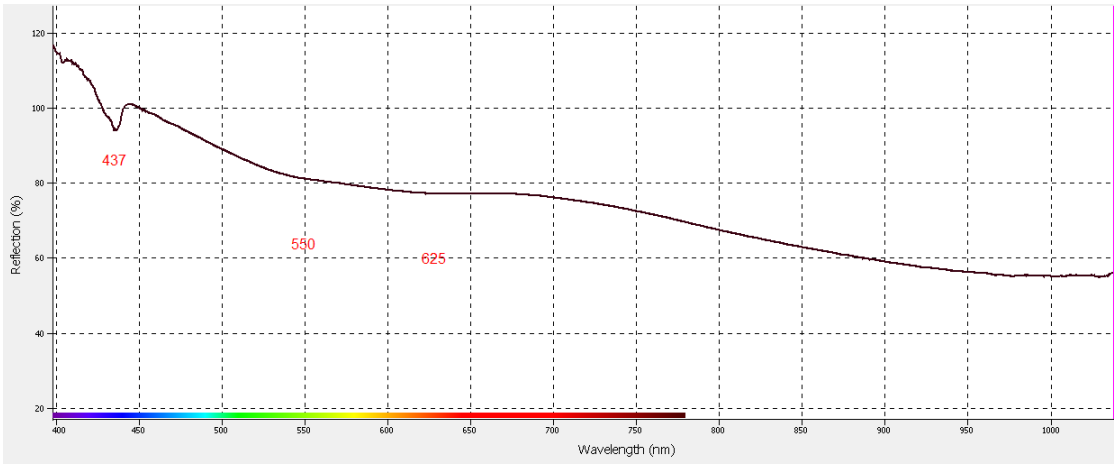
16: necklace 50 graduated lavender



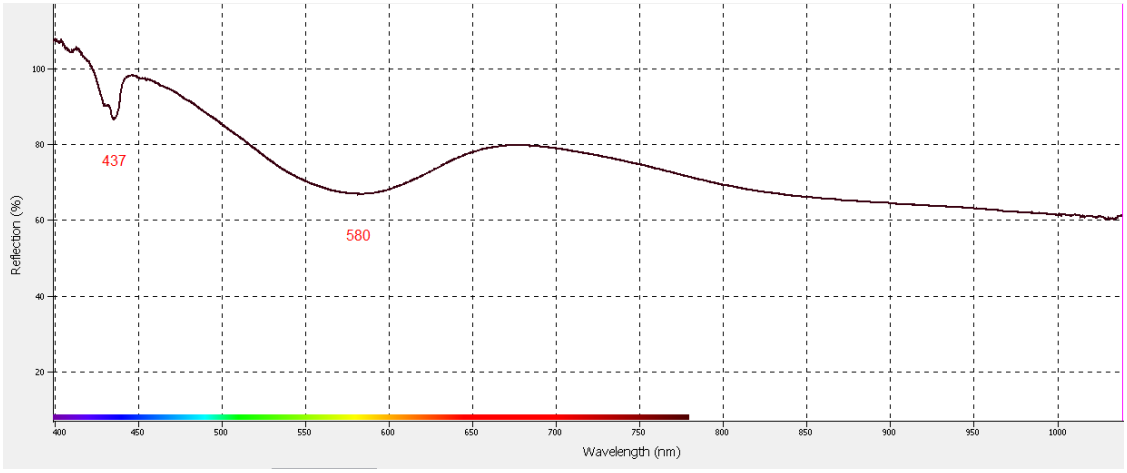
17a: sautoir: green beads



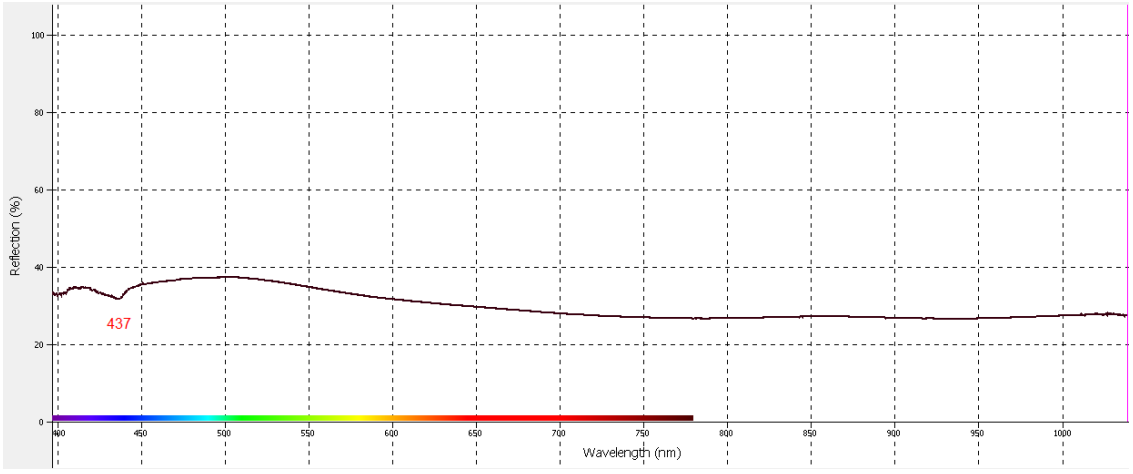
17b: sautoir: white beads



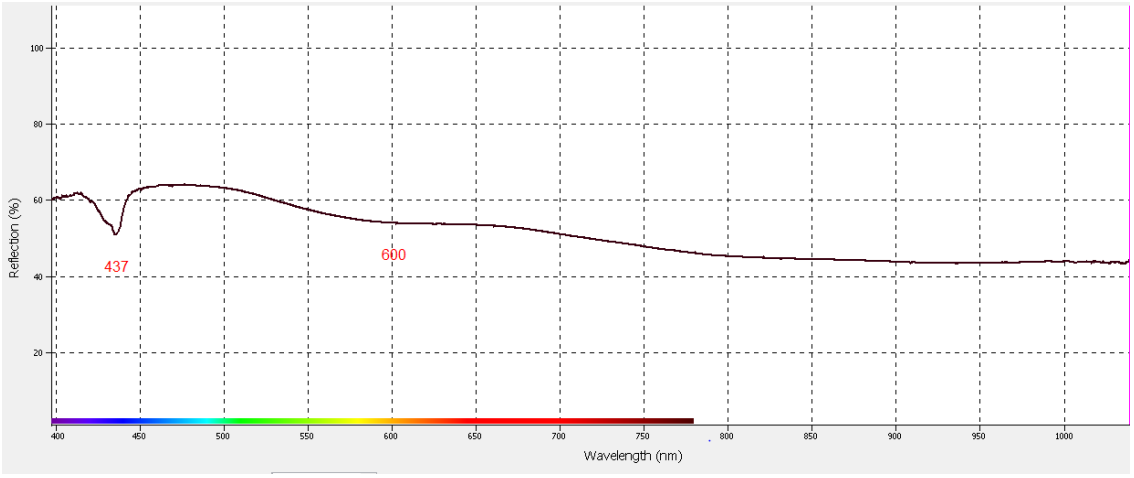
18: lavender goddess



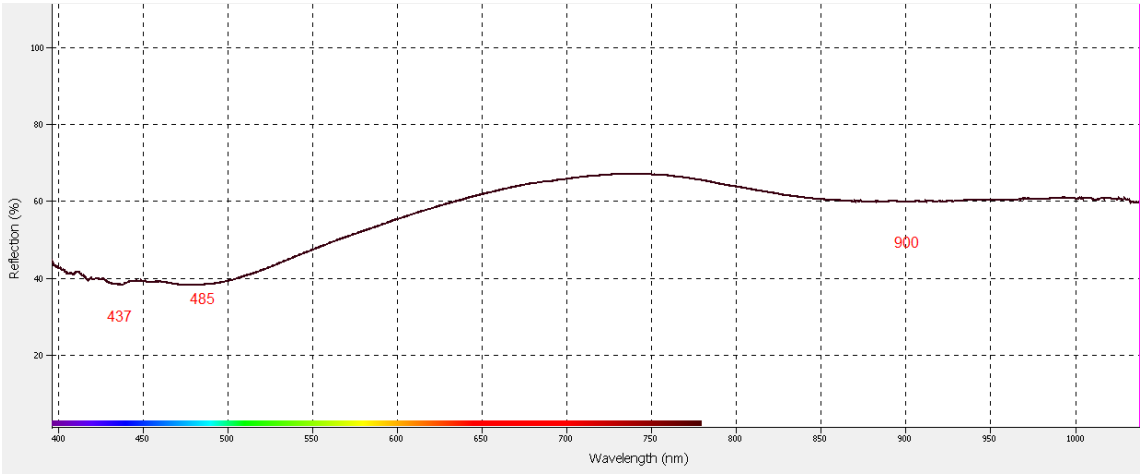
19a: green mini beads: dark green beads



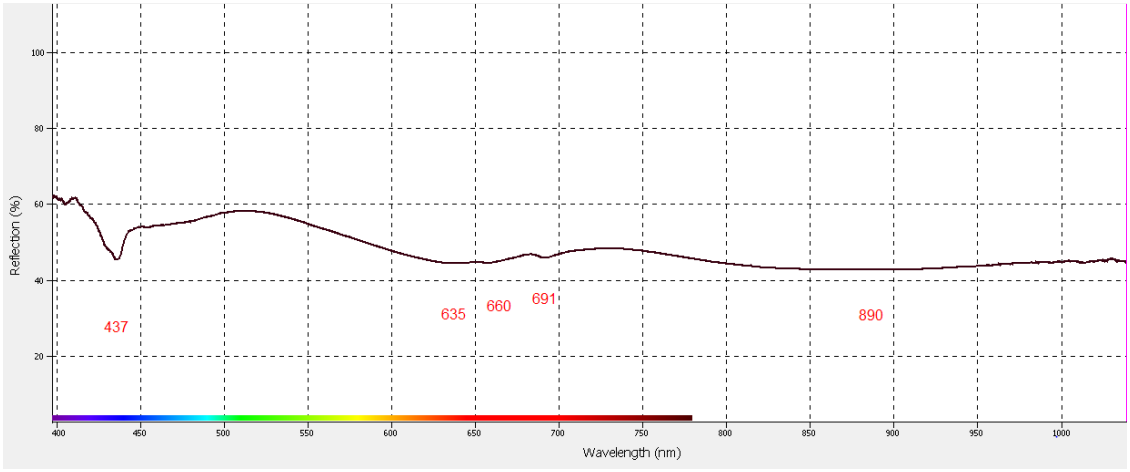
19b: green mini beads: light green beads



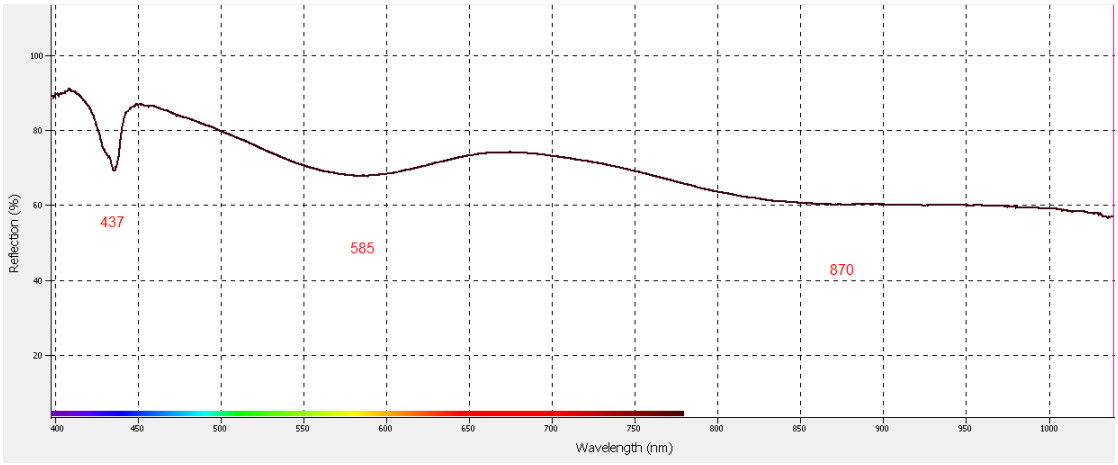
20a: mini brown beads



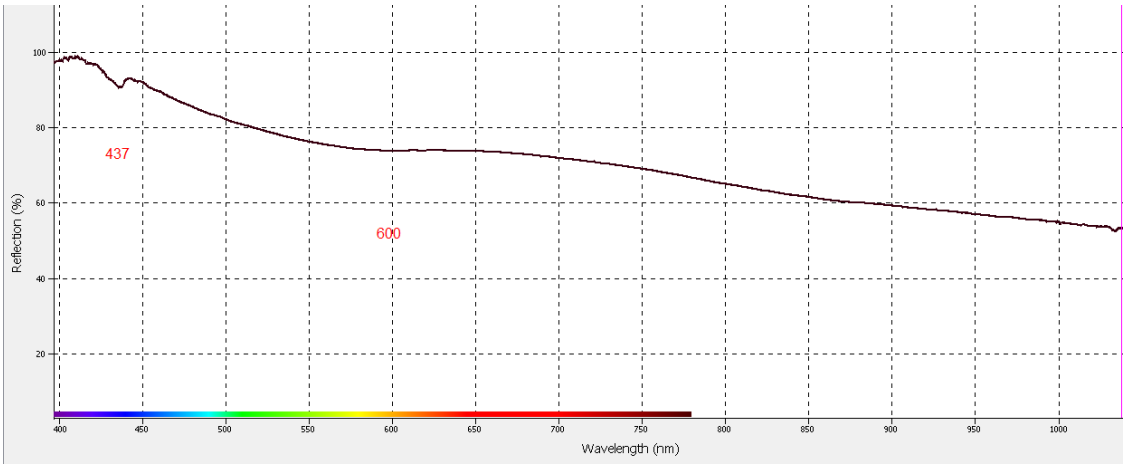
20b: mini green beads



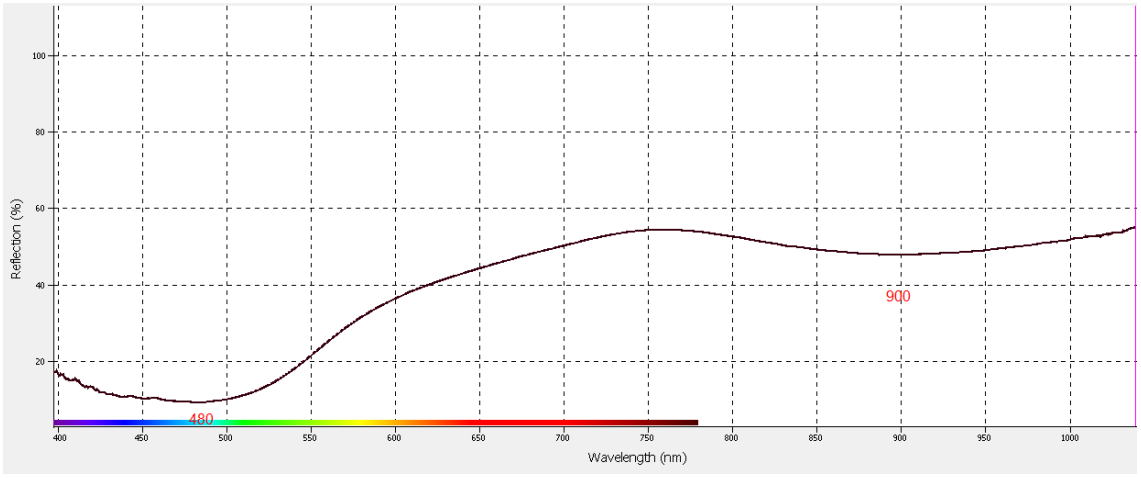
20c: mini white beads



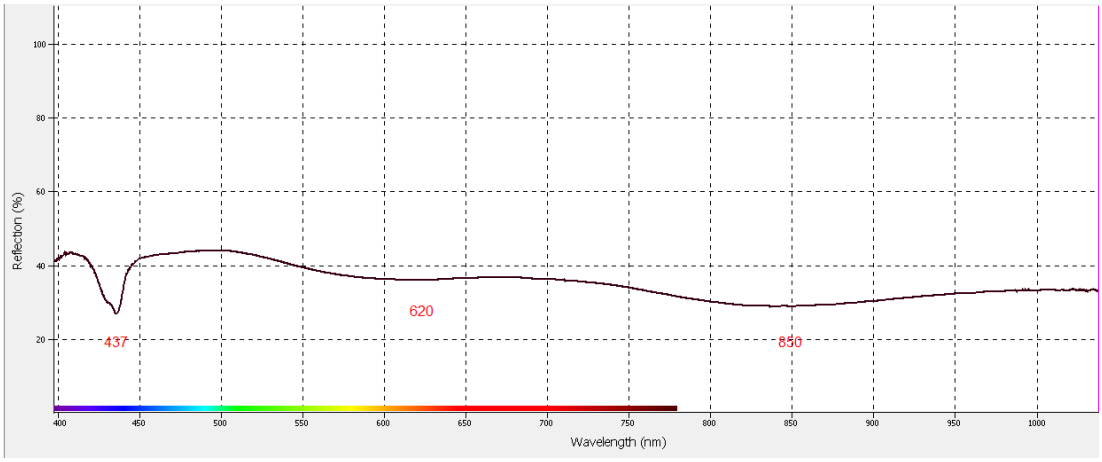
20d: mini light green beads



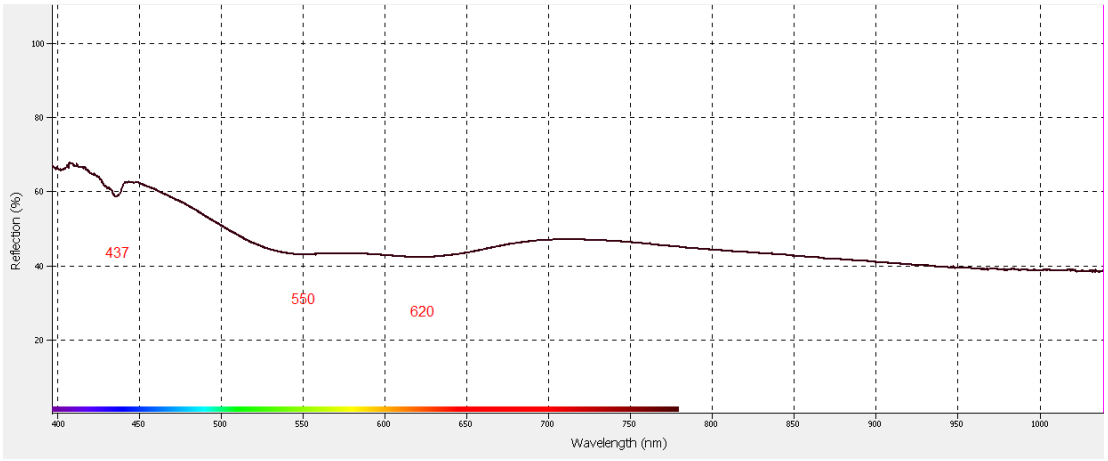
21a: mini brown beads



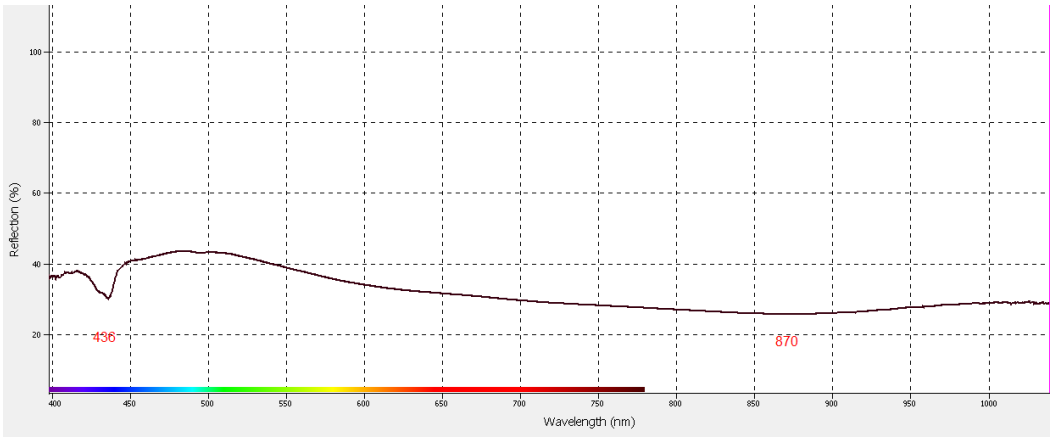
21b: mini green beads



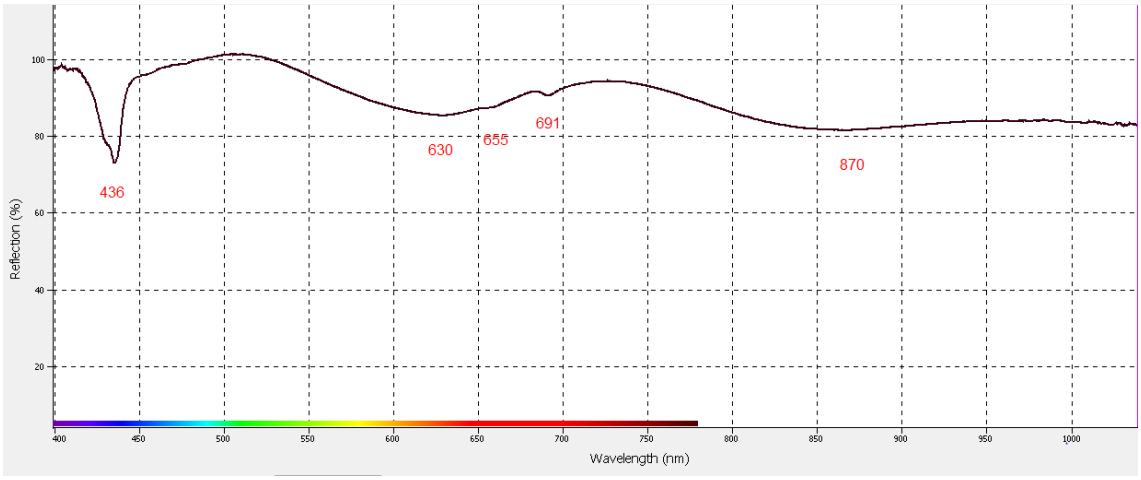
21c mini lavender beads



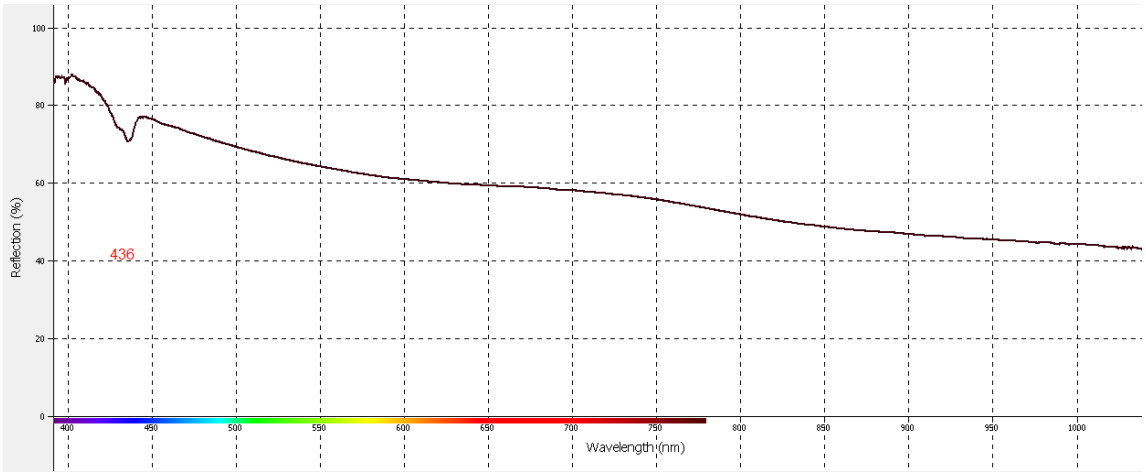
22a: bracelet gift: dark green beads



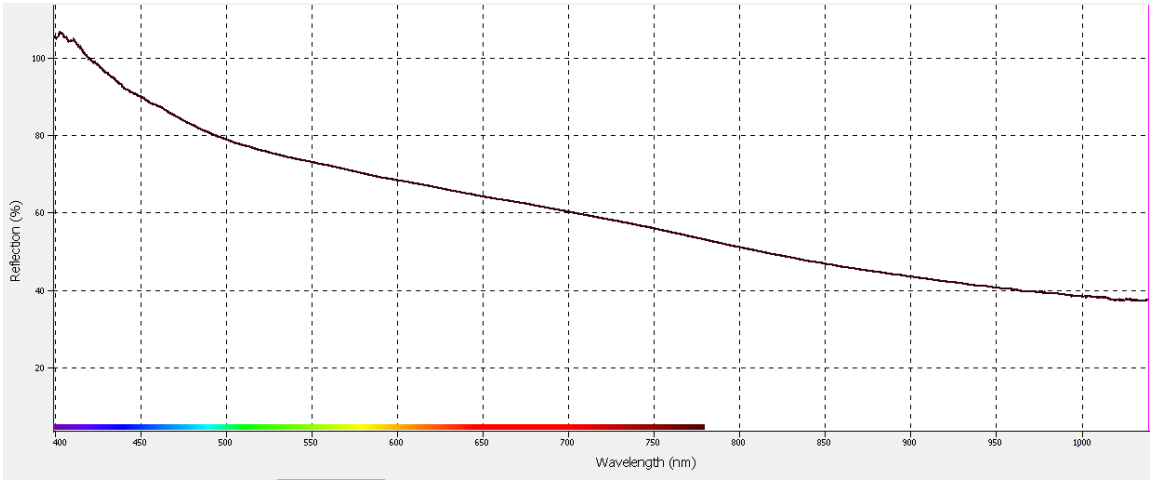
22b: bracelet green beads



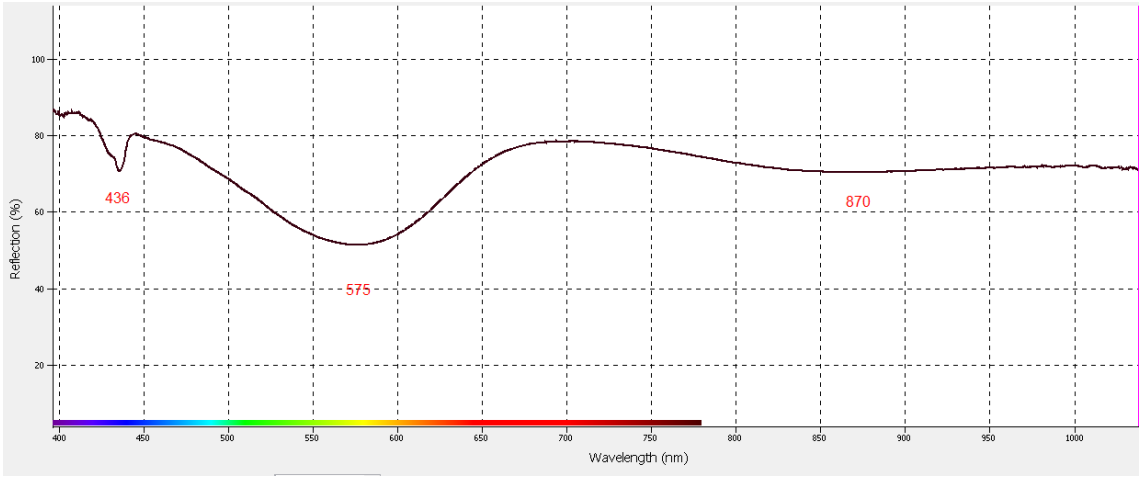
22c: bracelet gift: white fluffy beads



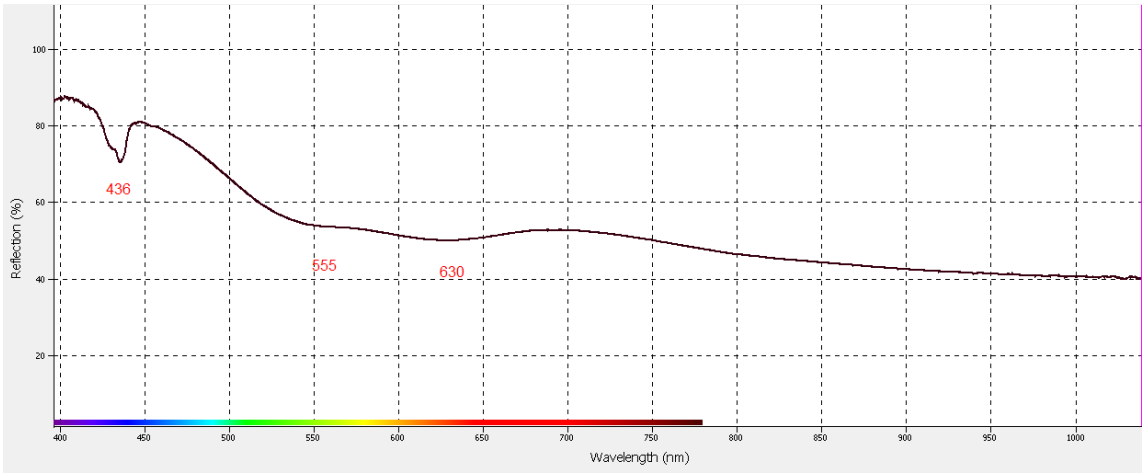
22d: bracelet gift white transparent beads



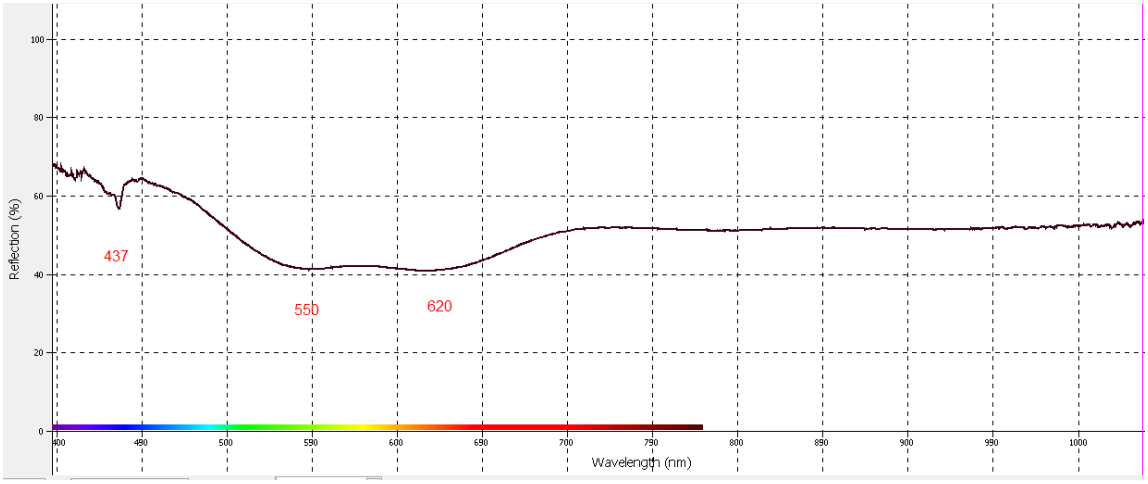
23: Cab 1 lavender



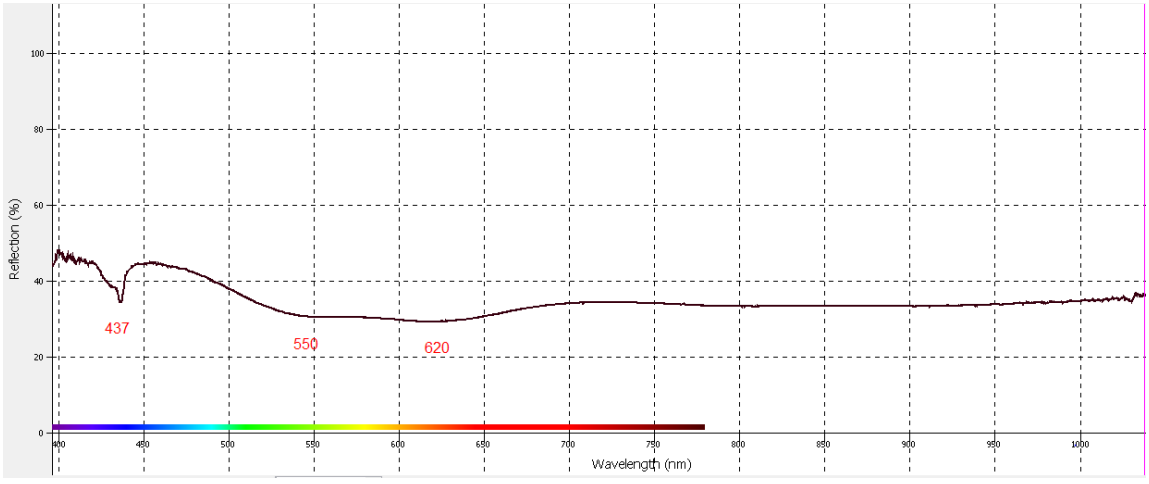
24: Cab 2 lavender



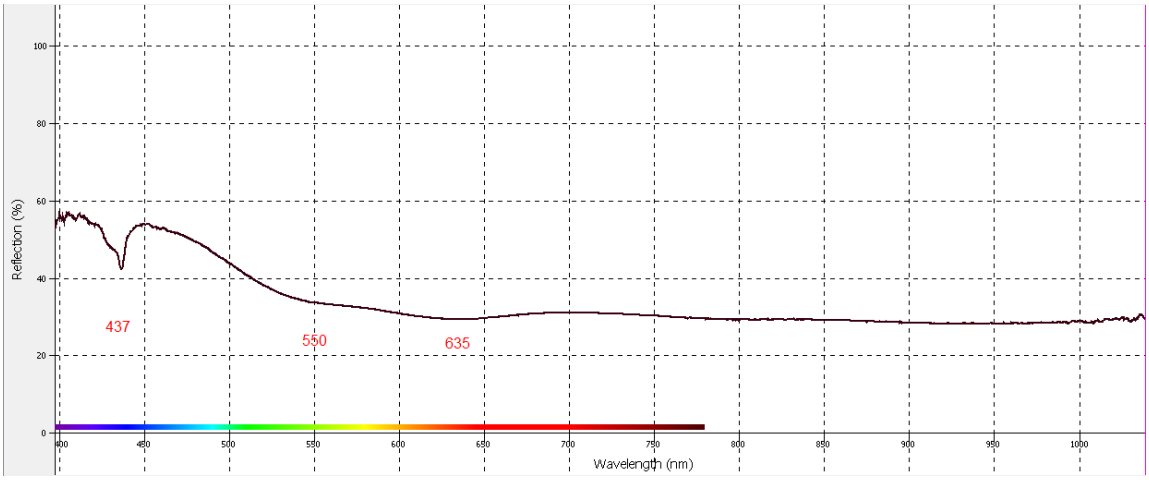
25: Cab 3 lavender



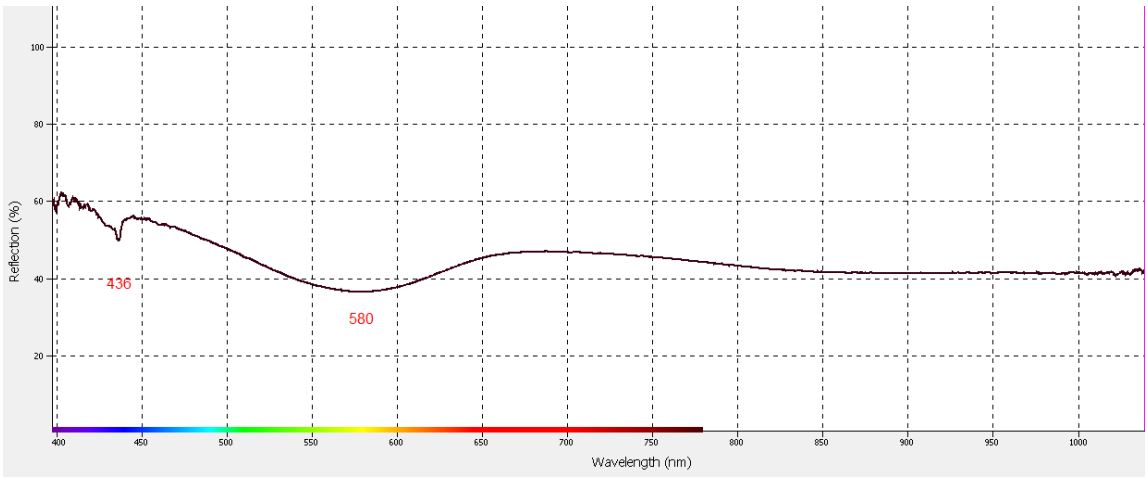
26: Cab 4: lavender



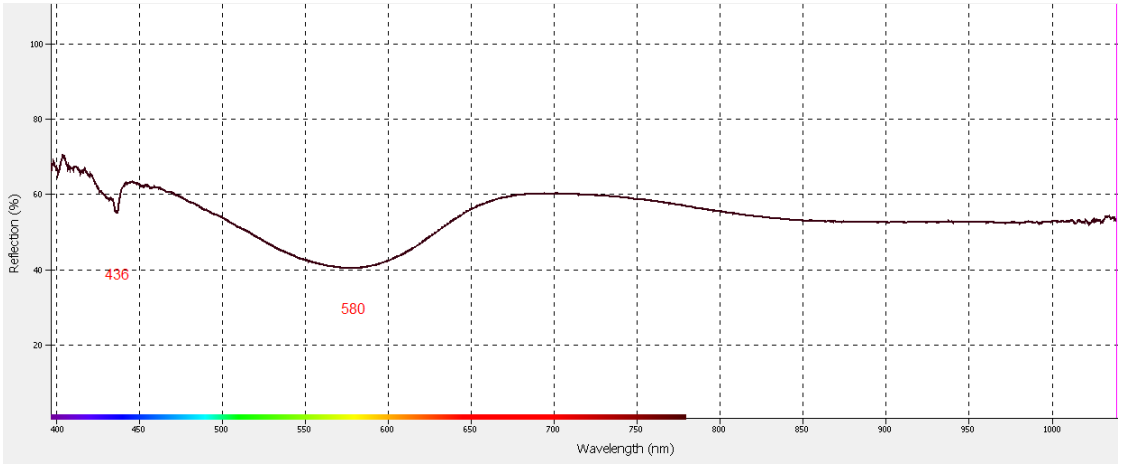
27: Cab 5 lavender



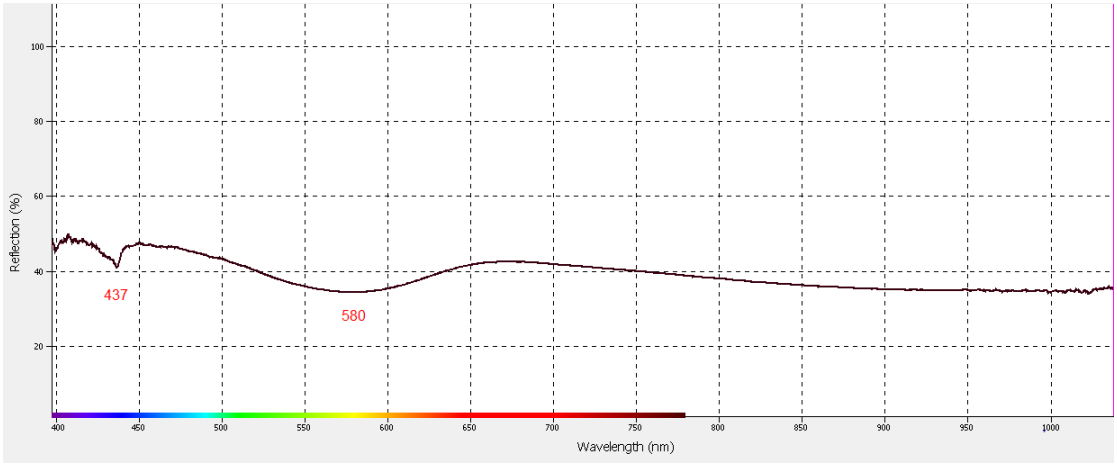
28: Cab 6 lavender



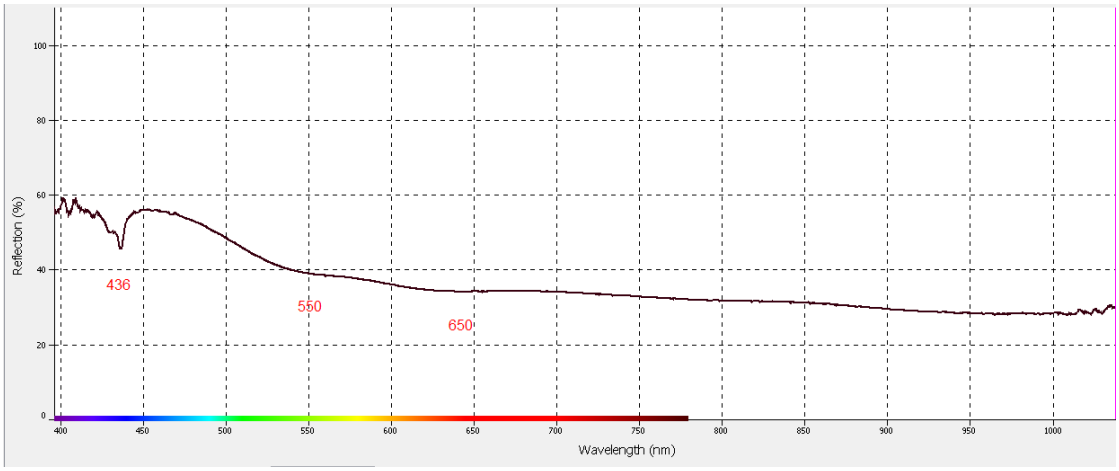
29: Cab 7 lavender



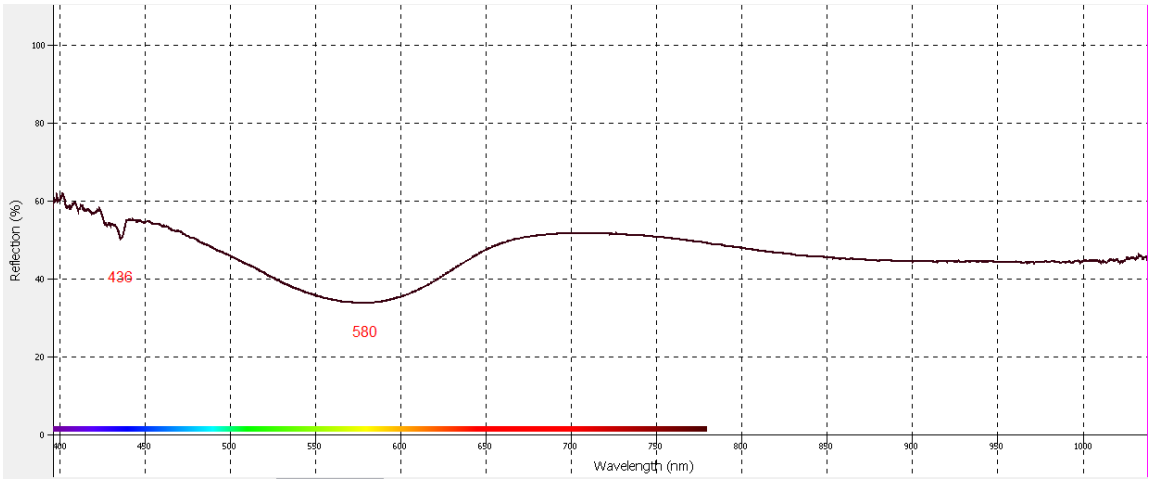
30: big cab dark lavender



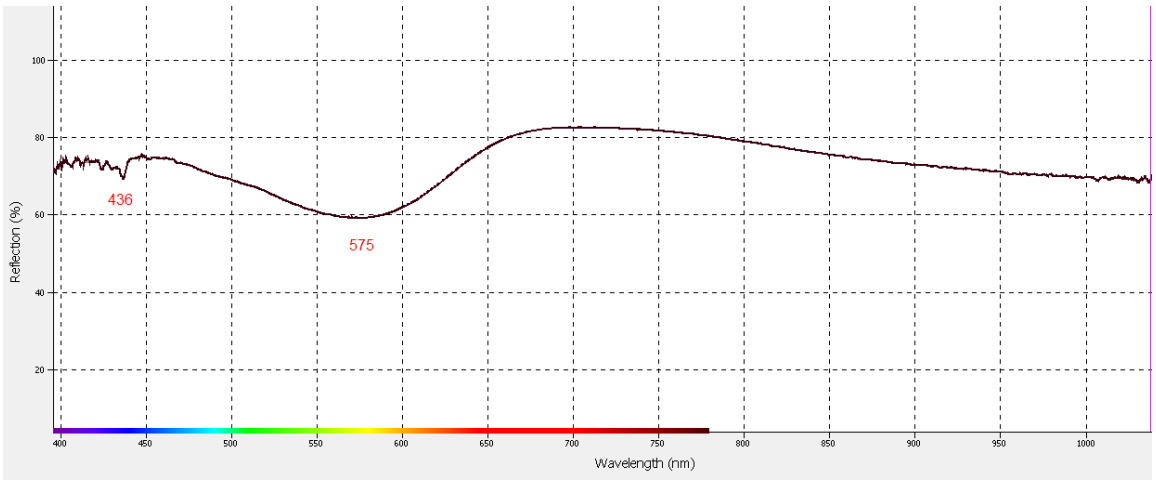
31: big cab lavender green spots



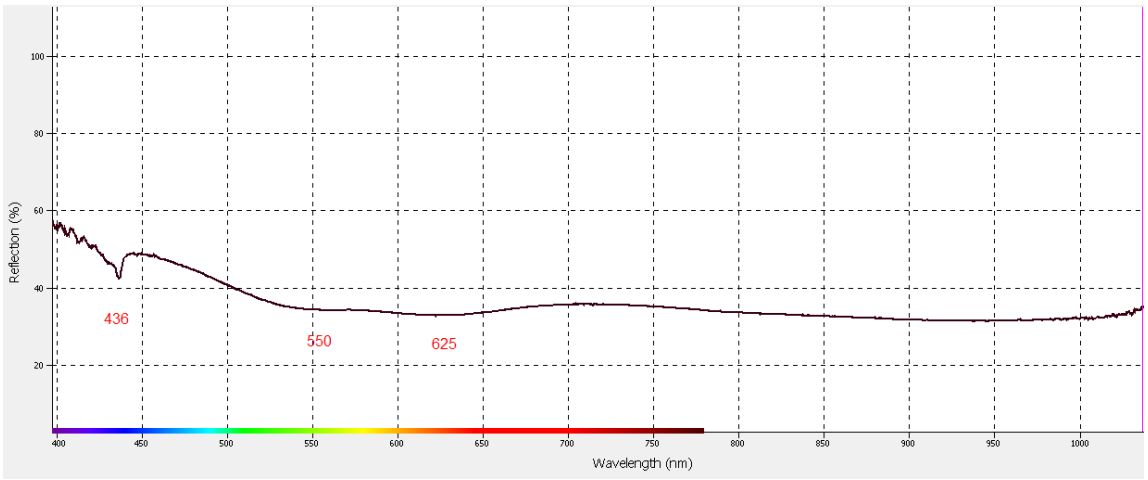
32: Big cab light and dark lavender



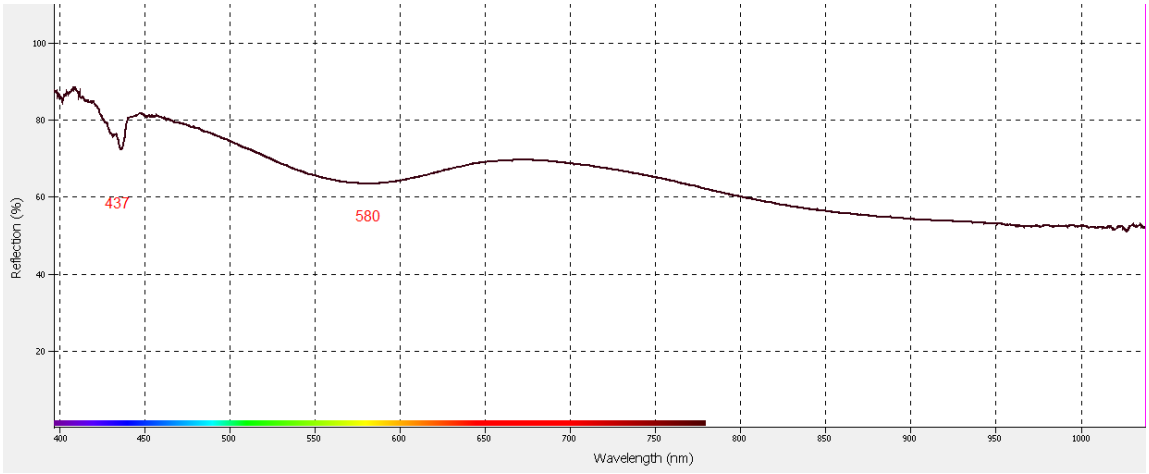
33: big cab lavender green bottom



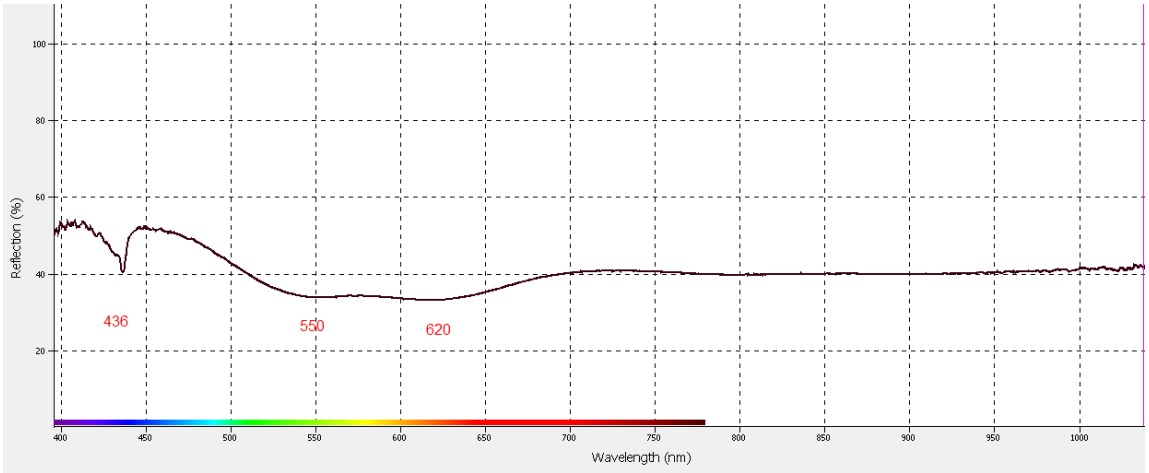
34: Cabs pair 1



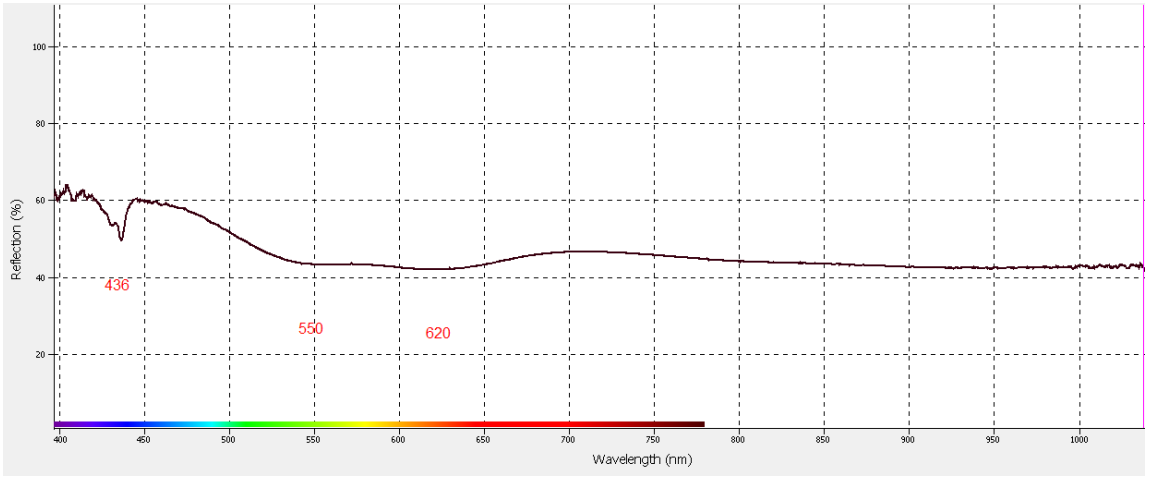
35: necklace 13mm beads white-light lavender



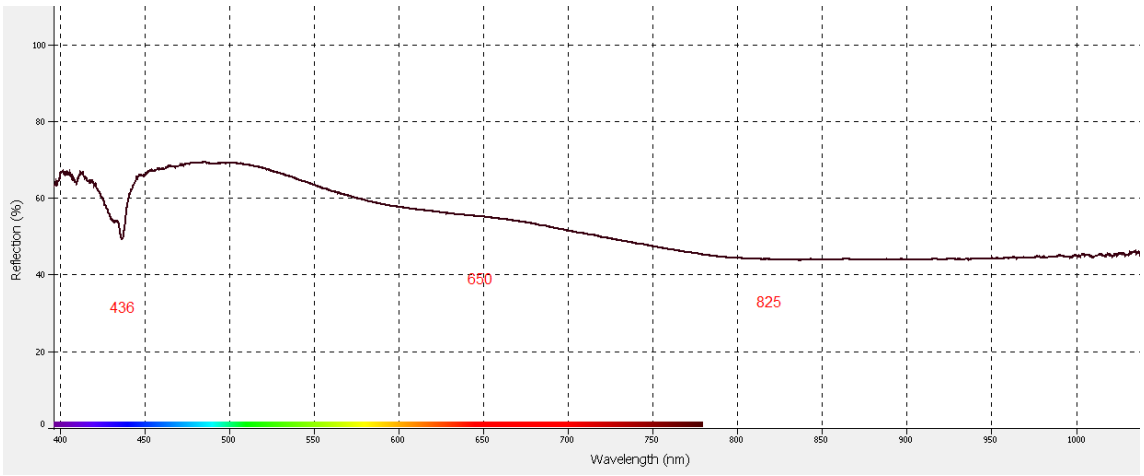
36: Cabs: pair 3 lavender



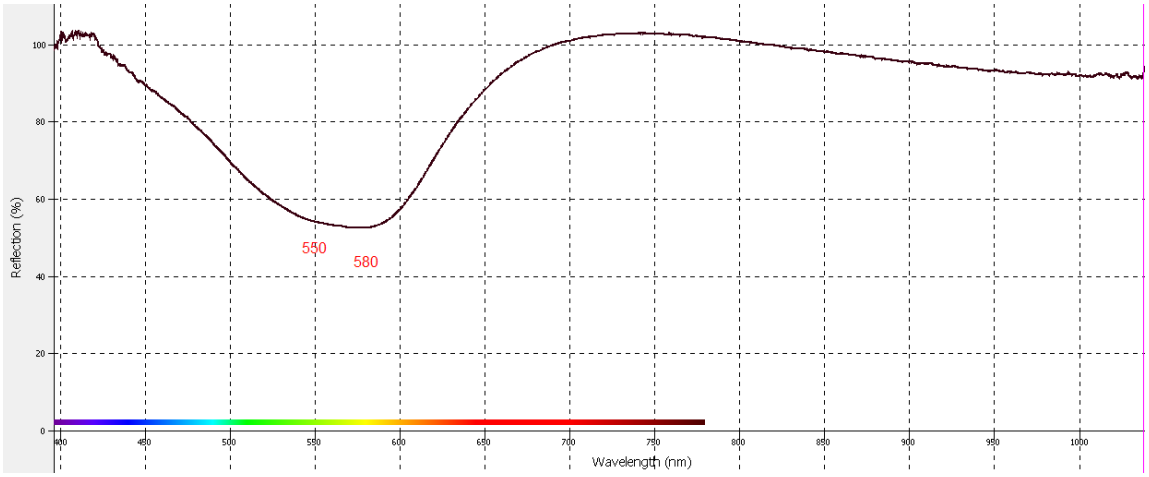
37: Cabs pair 4 lavender



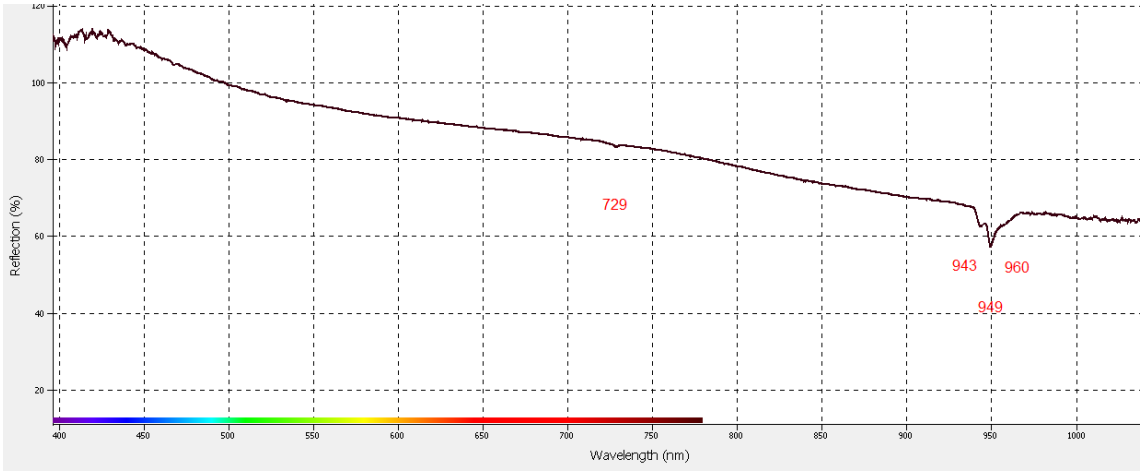
38: bracelet 14 beads discs green



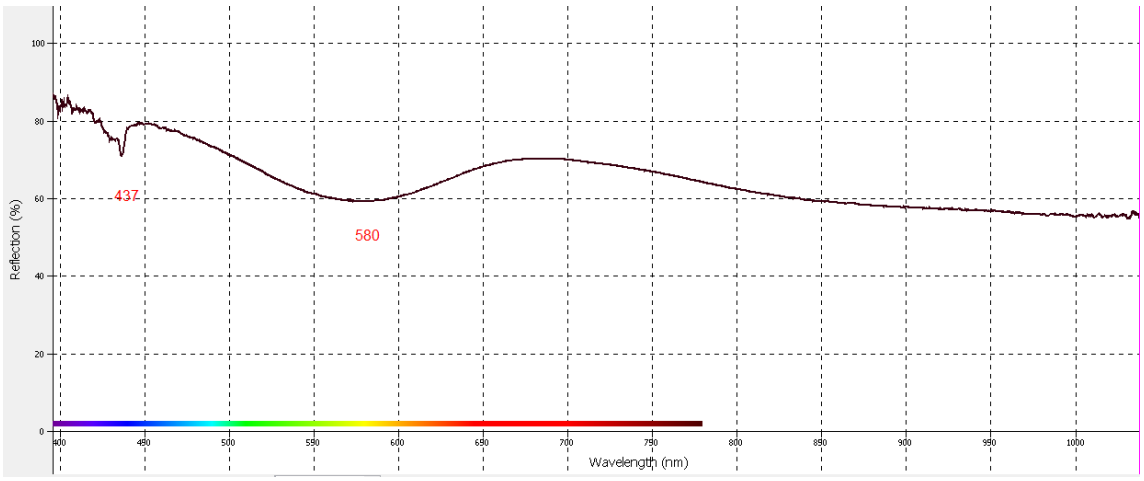
39: purple jade “EBAY” beads England



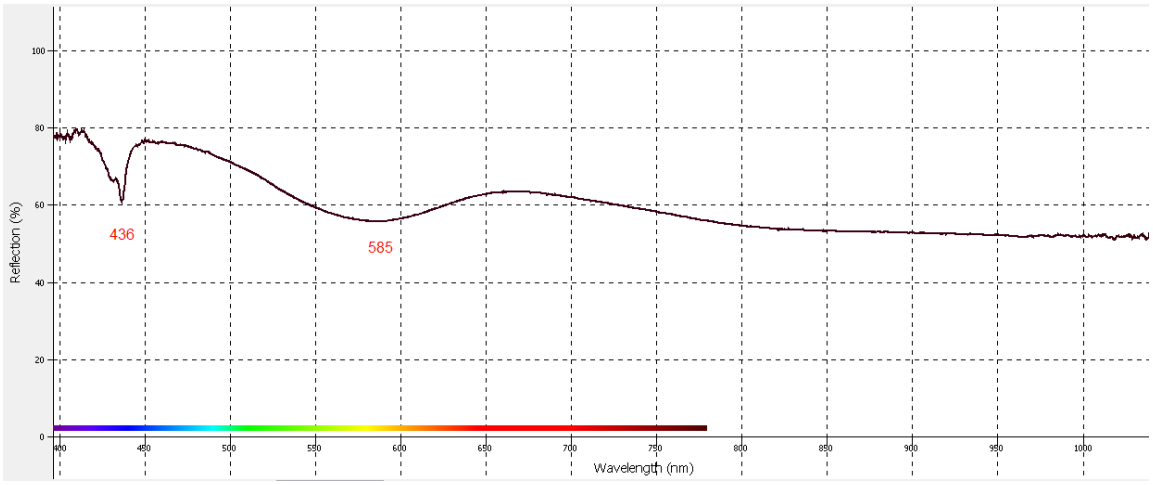
40: Lavender Bangle



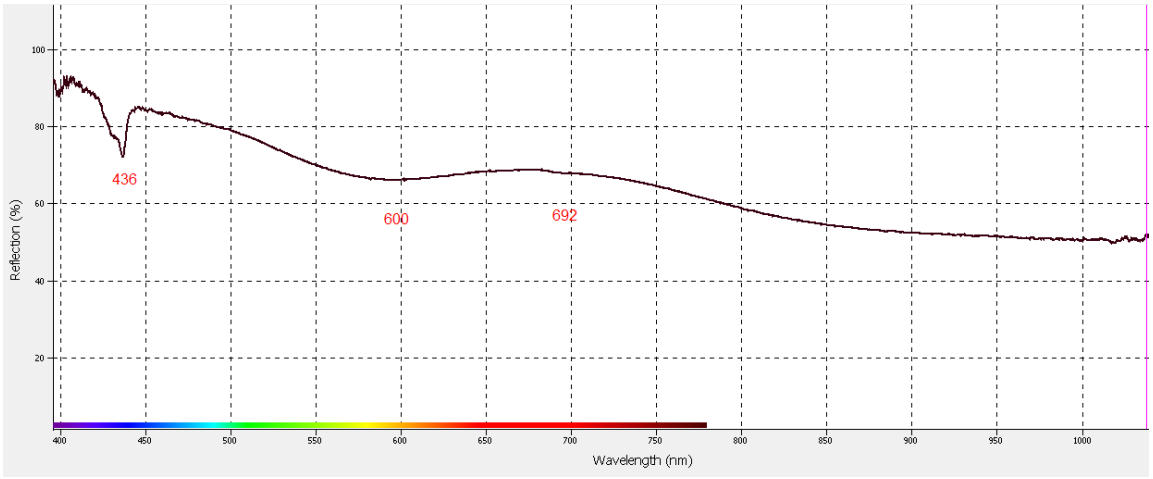
41: eagle pendant



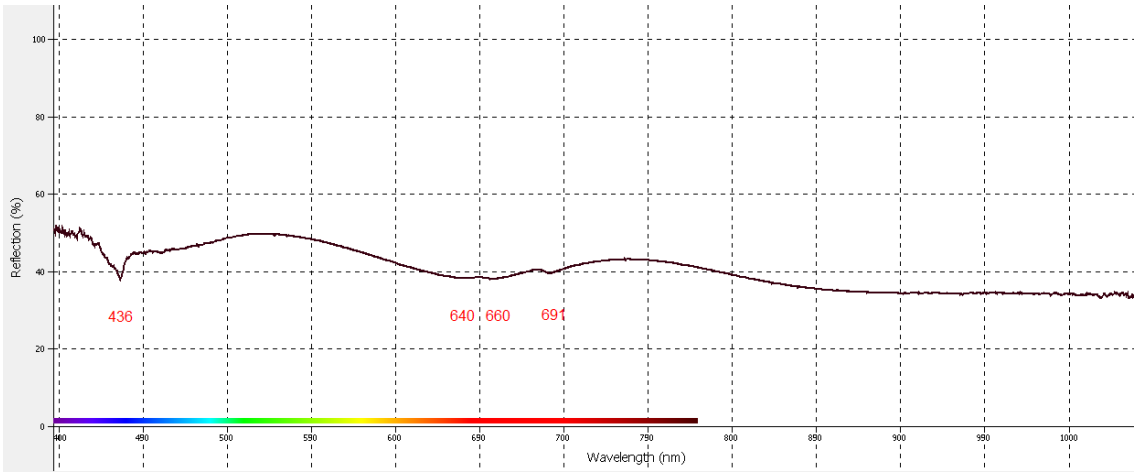
42: eggplant pendant



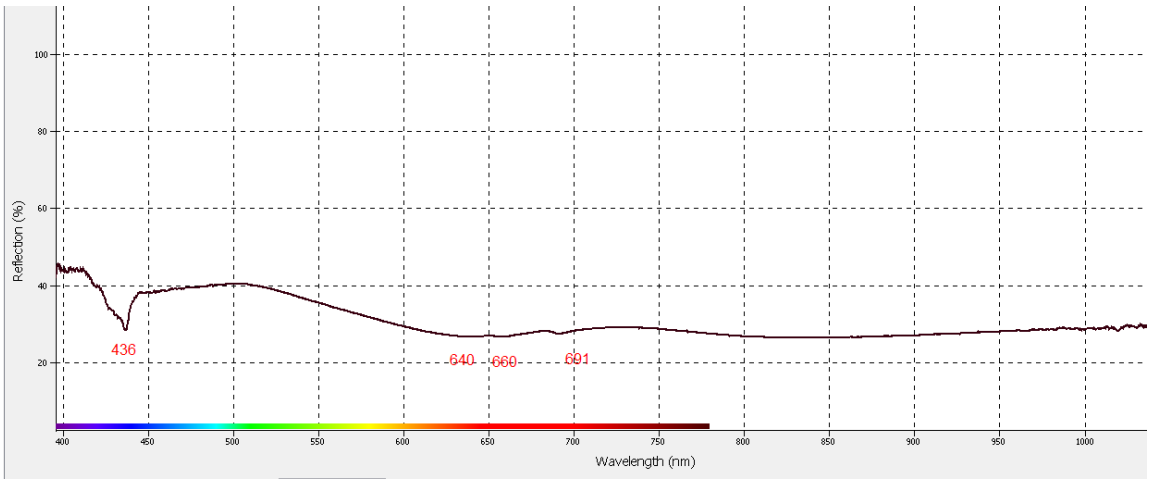
43a: fish pendant 3 circles: white-lavender part



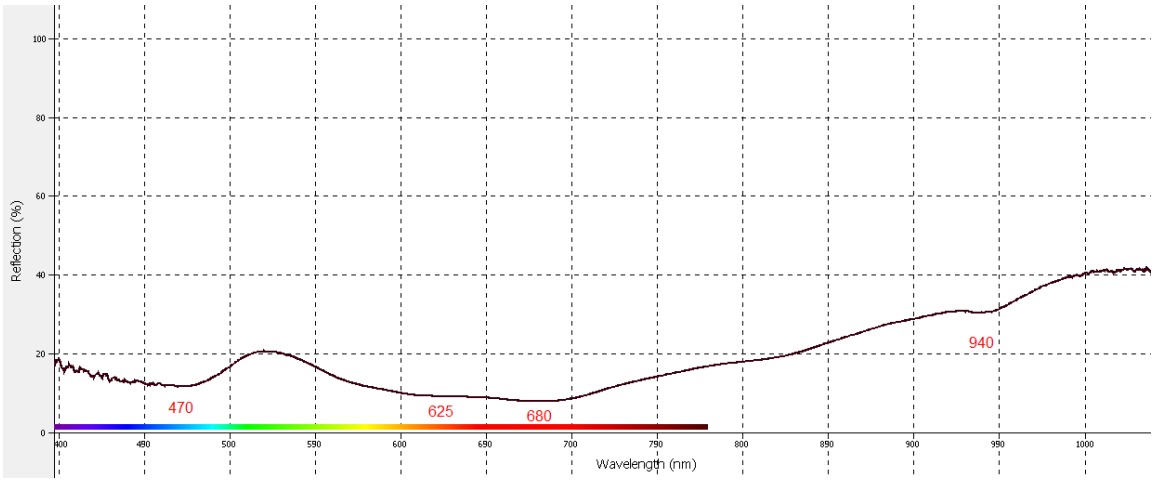
43b: fish pendant: green edge



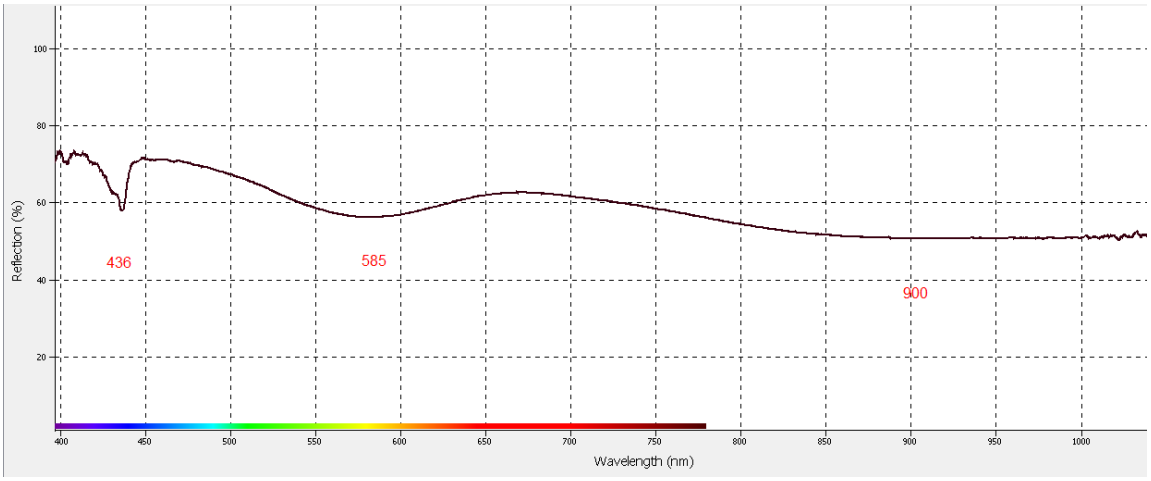
44: green swords pair



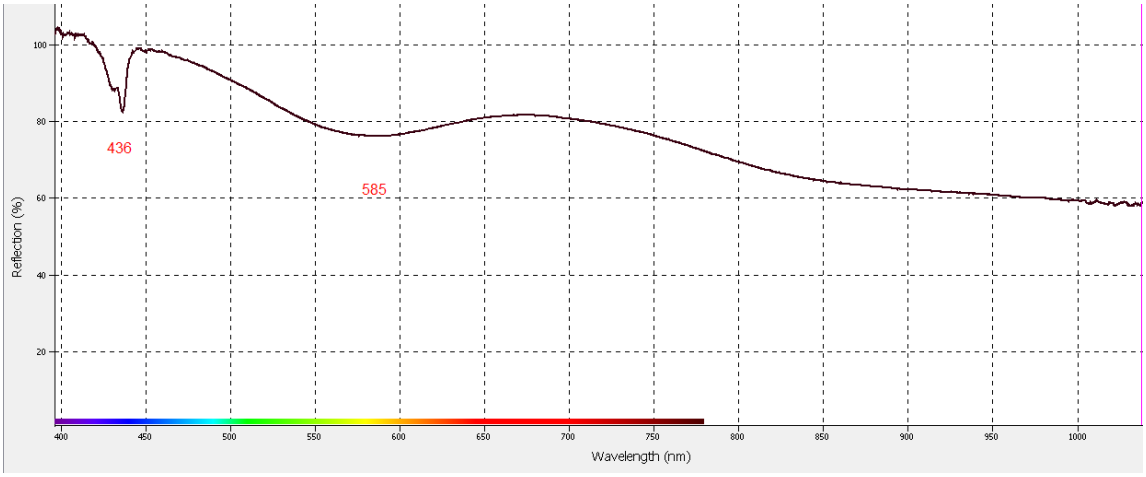
45: flower pendant green



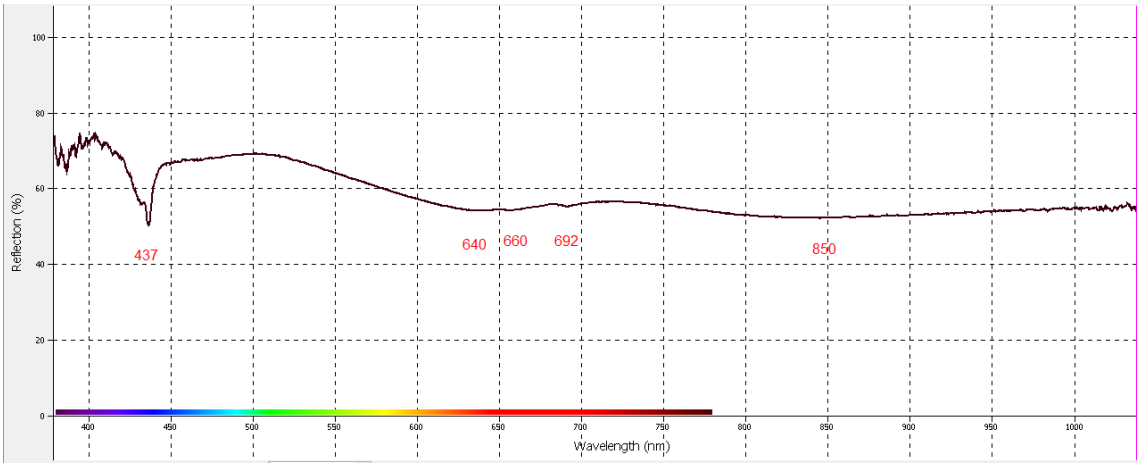
46: fish kissing



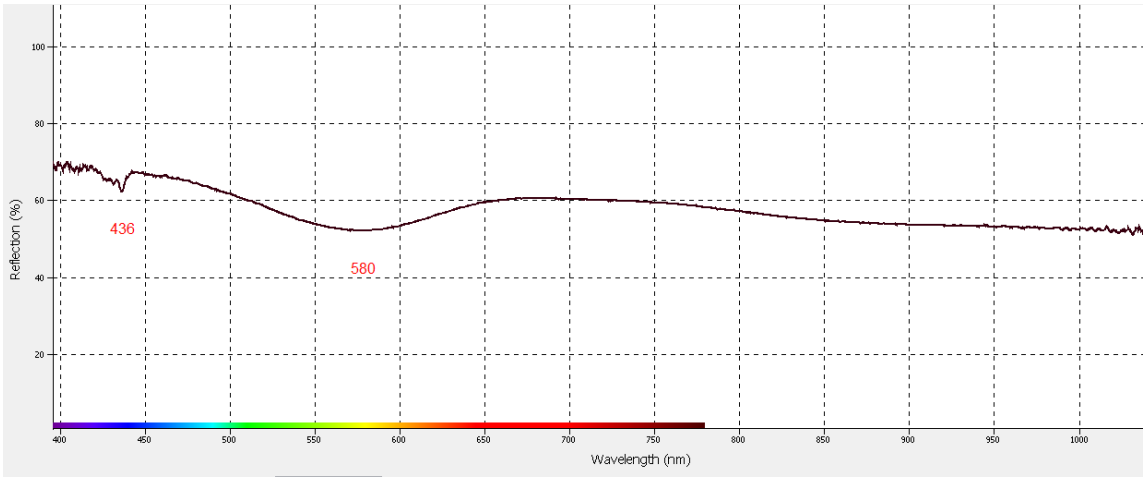
47: bracelet beads (green string)



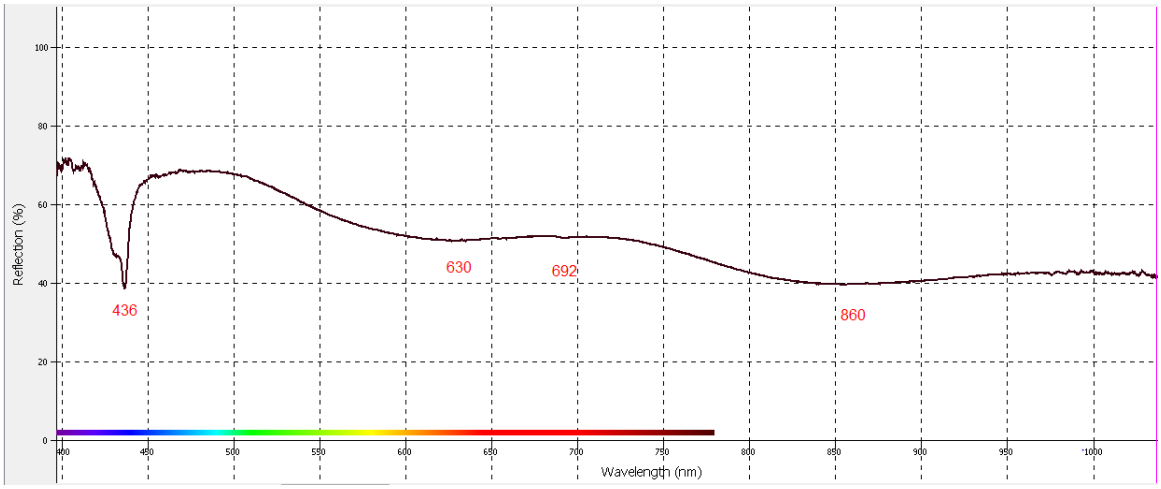
48: 16 barrel beads



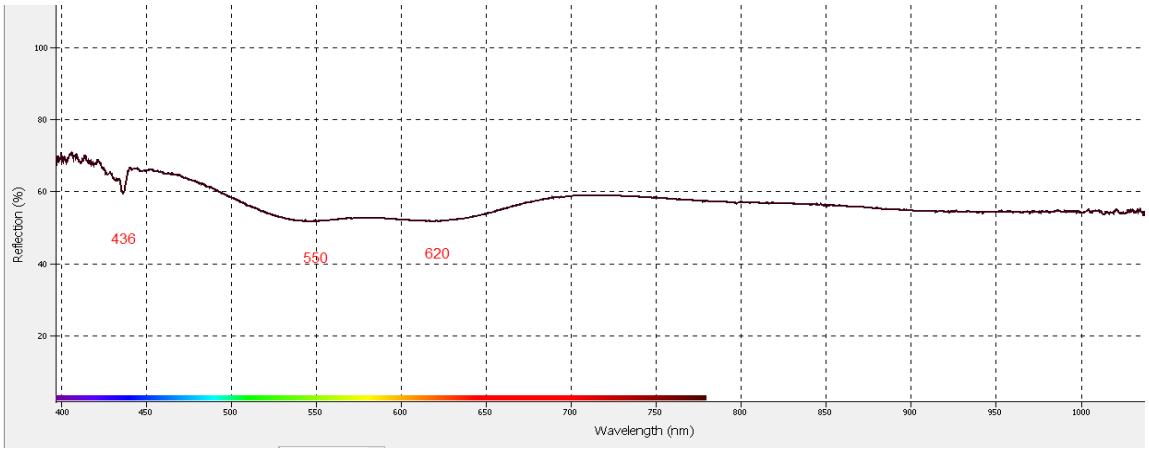
49: grape pendant



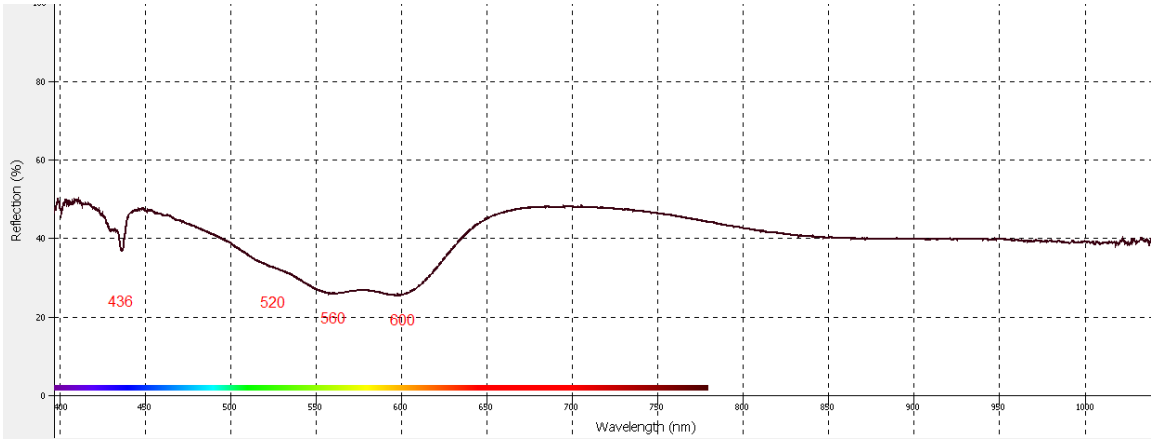
50: green lotus certified



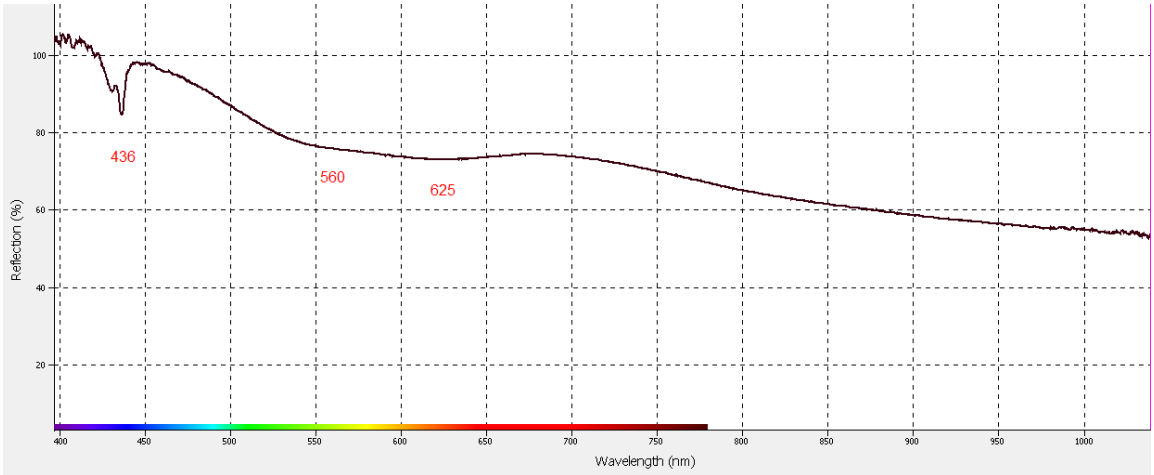
51: gold ring lavender cab



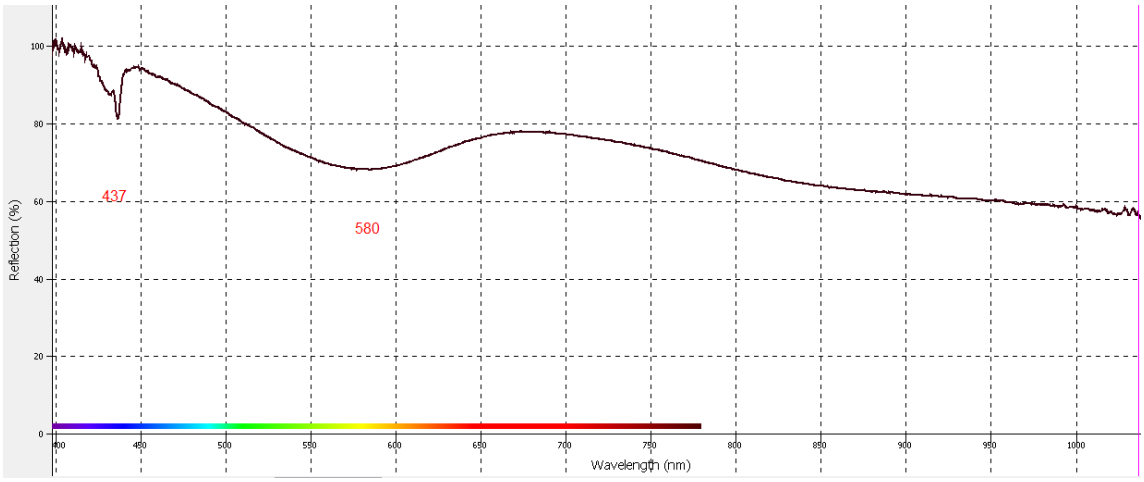
52: purple jade gold bracelet



53: necklace 44 beads



54: necklace barrel beads lavender



55: lions on cloud