A New Method of Dating:  
INFRARED LASER SPECTROSCOPY

Every North American archaeologist's dream is a method of dating artifacts directly – one that is 1) non-destructive, 2) rapid, 3) repeatable, and 4) affordable. Currently artifacts are dated by association with charcoal (that is to say, radiocarbon-dating) or by association with soil particles that have accumulated light (optically stimulated luminescence). Both dating methods are non-destructive and repeatable; however, they are slow and expensive.

Here I intend to discuss Infrared Laser Spectroscopy – a method of relative dating still in its infancy, but when mature, destined to be universally appreciated and applied. ILS is the brainchild of David Hunter Walley, an eccentric inventor who works out of the kitchen of a modest, clapboarded home in the rural community of Dorsey, near Fulton, northwestern Mississippi. Dave holds a patent for this archaeometric technique (Walley, 2012), which is unique because of its broad applicability to archaeological objects.

Dave, like most collectors of ancient artifacts, has confronted the problem of fakes. For some classes of objects, detecting fakes is challenging. Dating is required to sort authentic pieces from later copies. Standard methods of determining age, such as radio-carbon dating and thermoluminescence dating (TL), are costly, destructive, slow, and beyond the means of common men. Too, these techniques cannot be applied in all cases.

I recall one evening several years ago discussing with Dave the challenge of establishing the age of artifacts; I noted his determination to do something about it. A few months later he telephoned me and described what he thought was an ideal technique for authenticating and relative dating. I was witnessing the birth of Infrared Laser Spectroscopy.

The Method

In 1928 C. V. Raman and S. K. Krishman, as well as other scholars working independently, observed that monochromatic light reflected back from a target shifted frequency. Eventually it was established that shifting resulted because bonds between atomic elements fluoresced when bathed in strong monochromatic light. The wavelength signatures of fluorescing atomic bonds provided a means of testing for specific atomic elements and a way of gauging purity – as in case of diamonds offered for sale by jewelers. Graphs of fluorescing carbon-carbon bonds of pure diamonds are sharp and strong; while, impure diamonds yield light output
that is less focused, that is to say, of greater band width.

These days lasers are the best source of narrow band-width energy used to stimulate fluorescence in atomic bonds. Infrared lasers generate fluorescence as well as or better than laser beams of shorter wavelengths in the visible spectrum. Analysts, however, have observed an unwelcome side-effect known as STOKES SCATTERING. Stokes Scattering swamps fluorescent light signals making graphs difficult to read. Infrared laser beams are particularly good at causing Stokes Scattering.

Stokes Scattering occurs when infrared energy causes high-energy electrons that have been trapped within atomic structures (because of collisions with radioactive particles) to fall back to a lower energy state and to give off energy – frequently in the form of visible light. An old weathered rock, especially, if stimulated by an infrared laser beam, will be seen within a darkened room to glow briefly but intensely.

Dave Walley realized that Stokes Scattering offered a straightforward means to determine whether or not the surface of an artifact had been exposed to radioactive particles. If more electrons had accumulated at an artifact’s surface than elsewhere within it, then clearly the artifact had been exposed for a lengthy period and was genuine. A modern-made artifact, on the other hand, would show no difference in the amount of Stokes Scattering between its interior and surface. The surface of a freshly-made artifact has had no opportunity to be affected by radioactive particles within a natural environment, and electrons have not been concentrated within traps at its surface.

The gaseous element radon, atomic number 86, with its many radioactive isotopes, is particularly effective in boosting electrons near the surface of an artifact to higher energy states. The isotope Radon-222 is a strong alpha-particle emitter, but it has a half-life of only a few days. Nonetheless, it is being generated constantly by the decay of Uranium-238 via Thorium-230. Uranium is widespread in nature; we are surrounded by it and constantly subjected to its influence.

Artifacts in the ground are affected by Radon-222 dissolved in rainwater. The intimate contact of wetted artifacts with radon promotes damage by alpha particles, generating high-energy electrons that enter traps at the artifact’s surface.

The amount of radon in the soil varies from region to region because the abundance of uranium is not uniform. The chemical composition of bedrock or bedrock particles within sediments themselves, has a direct bearing upon radon production. Alluvial soils rich in radon-poor quartz grains will have small radioactivity and low radon values; while, soils overlying granite and black shales can have excessive, even dangerous, amounts of radon. Clearly, when assessing the amount of electron energy that has accumulated at the surface of an artifact, it
is necessary to have some idea of what was its original environment of deposition. For artifacts of the same age, quite different amounts of light will have accumulated in specimens coming from river alluvium compared to specimens resting within upland, residual soils upon bedrock.

**Measuring Light at the Surface of Artifacts**

Applying the beam of a one-watt infrared laser to the surface of an ancient arrowhead for one second is sufficient to generate a measurable amount of visible light. Using a photo-multiplied, coupled device the light can be registered as a curve. The area under this curve is the best measure of light intensity; however, in practice, one just records the numerical value of the peak of the curve. An averaged value for five or six applications of the laser to EACH SIDE of the arrowhead is required for a meaningful result.

If time and money were no object, one would prefer to apply the laser beam 50-60 times to both faces of an arrowhead and to average the results. By doing so, precision would increase—the standard deviation of the averaged value would decrease to plus-or-minus 5% and perhaps even less.

It is important to measure both sides of a flat object, like an arrowhead, as the side facing up when it lay buried in the earth was wetted more often by rainwater with dissolved radon. One would expect this upward-facing side to yield an higher averaged light value than the downward-facing side. Experimentally, we often do observe a difference between sides; therefore, averaged values from both sides are combined for a single result.

We also observe that artifacts of some raw materials yield high light values; while, artifacts of equivalent age made of different raw materials may have negligible amounts. Such variation among raw materials is complex, but we are able to offer some explanations. In my opinion (see Gramly 2012) the amount of accumulated electrons depends upon the number of traps available to them. Some raw materials are deficient in traps, cannot accommodate many high-energy electrons, and will give low light values. On the other hand, certain rocks like Ft. Payne chert, which was a favorite toolstone throughout prehistory, are able to accumulate many high-energy electrons at their surface. Ft. Payne chert is very rich in organics, which are dispersed throughout its silicate structure. Bacteria living anaerobically* within the rock’s surface feed upon these organic materials. Their waste products and their own cellular structures, I hypothesize, provide many traps for electrons; while, chemically purer, less “nutritious” raw materials cannot support many bacteria and have fewer electron traps.
*Oxide salts of barium figure into the respiration of bacteria who live without atmospheric oxygen inside of rocks. Older artifacts show higher concentrations of barium than do younger artifacts. Thus, barium values also provide a means of relative dating (Gramly 2012).

If we want meaningful comparisons of light values among different arrowheads, we must know something about the raw materials used to make them. And, as I have already suggested, one should understand where those arrowheads were found — whether within alluvium or a residual soil, etc.

To obtain accurate light values for arrowheads of different ages, one must be sure that none have been heated strongly or burned. Modern forest fires might heat shallowly buried artifacts strongly causing an unknown number of electrons in traps to fall back to lower energy states, releasing light, and skewing measured values. Burned artifacts will appear less ancient than they really are.

**Authenticating Versus Dating**

For many collectors it is enough to know that an artifact is a genuine antiquity, not a later fabrication. For arrowheads, if light values measured by ILS are uniform everywhere on each face and for both faces, our suspicions are aroused. To be even surer that an arrowhead is a fake, one should measure light values both within the radon-damaged zone at the rock's surface and within the unweathered zone deeper inside the arrowhead. In order to measure light deep within an arrowhead, cutting into it might seem necessary. Dave Walley and I are strongly opposed to such destructive acts. Therefore, Dave developed the technique of “virtually focusing” a laser beam. This technique, whose mechanics are still not understood, enables an operator to measure light deep within a raw material WITHOUT any influence from the layers through which it passes!! No chipping or cutting of an arrowhead is required. This revolutionary discovery is outlined in David Hunter Walley’s patent for the ILS system. Some day perhaps virtually focused laser beams will be used in surgery to target diseased tissues; the healthy tissues through which the laser beams pass will be less strongly affected.

Another rapid test that can confirm suspicions about an artifact’s authenticity is to apply a laser beam or other strong energy source at the blue end of the visible spectrum. Biogenic organisms fluoresce when bathed in blue light and ultra-violet — a behavior that has been well known to micro-biologists for 20 years. Arrowheads that are weathered and ancient, harbor bacteria and their by-products. Therefore, a truly ancient arrowhead of Ft. Payne chert or another rock that is “tasty” to bacteria, will glow yellow, orange, or red in strong blue light.
Dave Walley offers a commercial device that enables the user to detect fluorescence at the surface of an ancient arrowhead. This device is known as an "Archeoscope," but I have dubbed it the "Wallyscope."

Wallyscopes have been used to detect fluorescence within cracks in the glaze of ancient Chinese porcelains and stoneware, sparing collectors from making bad purchases. Modern copies will exhibit no such fluorescence — they never were buried within tombs.

For a research archaeologist like me, however, the true importance of ILS is as an instrument for relative dating. I say "relative" because the ILS method is not directly tied into a radioactive clock like the "absolute" dating techniques of 1) radio-carbon, 2) potassium-argon, 3) fission-track, or 4) optically stimulated luminescence (OSL). When we measure the amount of light released by high-energy electrons falling back to lower-energy states, these values in part depend upon the absolute age of the arrowhead being studied. An arrowhead's absolute age can only be known by its association with radiometrically dated materials, such as charcoal in a hearth. Still, if we assume that an authentic Clovis point is roughly 13,000 calendar years old, as established by radiocarbon dating time after time everywhere across the country, then ILS tells how much light accumulated during 13,000 years in a Clovis point of a specific raw material that lay buried within a specific soil type. It follows, that the age of an another unburned arrowhead but made of the same raw material as the Clovis point and from similar soil can be known by simple mathematics:

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\frac{\text{# light units for Clovis point}}{13,000 \text{ calendar years}} = \frac{\text{# light units for unburned arrowhead}}{X}
\]

At the Bates Pond Beach site in Colbert County, northern Alabama, for example, we used ILS to measure light values for a Clovis point preform and a typical triangular endscraper — both presumably about 13,000 calendar years old. The preform gave an averaged value of 76,750 light units; while, the endscraper was nearly the same — 76,150 light units. Then, we measured the light units for a Lost Lake point from the same site. The result was 55,725 units. Solving the equation for "X" the calendar year age of the Lost Lake point was found to be 9,474 years before present. This result is in perfect harmony with the range of radiocarbon ages for all manner of Lost Lake points (see Perino 1986: 232), which give a grand calibrated mean of 9,240 calendar years.
It is important to note that for this small experiment the raw material of both the Clovis artifacts and the Lost Lake point is Ft. Payne chert, and, of course, all three artifacts were recovered from the same type of soil.

To recap, the measured relative age is 9,474 years for the Lost Lake point and the calibrated absolute age of the Lost Lake type is 9,240 years — a difference of less than 250 years and likely statistically insignificant.

Another experiment that demonstrates the value of ILS for relative dating — again from Colbert County, Alabama — involves 22 Ft. Payne chert projectile points that were found by a single collector on the surface of the well-known Heaven’s Half Acre site, aka the 6th Street site. Since 1960 many hundreds, perhaps thousands, of Palaeo-American and Very Early Archaic (Dalton, Beaver Lake, etc.) points have been reported from Heaven’s Half Acre (King 2007). The site is located upon a residual soil within a low-relief, karstic topography south of the Tennessee River.

After typing this small assemblage, an averaged light value was obtained for each specimen. Five readings on both faces were made. The mean light value of the 12 Clovis points among the 22 points was found to be 71,982 (range 59,525-94,950). Four Late Stage Cumberland points had a group mean of 69,075 light units (range 65,275-72,250) — nearly identical to the results for the Clovis points. I was not surprised by this finding, as I have argued elsewhere (Gramly 2013) that Clovis split from the Cumberland Tradition during its Late Stage — approximately 13,500 calendar years ago. At the Heaven’s Half Acre, at least, there is no demonstrable age difference between Clovis and Late Stage Cumberland.

Of particular interest to me in this experiment were ILS readings for two Very Early Archaic points made of Ft. Payne chert. A Greerbiere point gave an averaged value of 58,050 light units; while, a Beaver Lake point had an averaged value of only 41,800 units. Both outcomes support a later age for these types than Clovis or Late Stage Cumberland. This finding is hardly revolutionary, but it does point out the need for statistically sound measurements and large sample sizes. The Greenbrier point’s averaged light value ALMOST overlapped the low end of the range of values for Clovis points from Heaven’s Half Acre. The outcome of measuring stored light energy within a single projectile point is not always deceptive — but it might be. The larger the measured sample — the more confident we are in the results.

Part of the power of the ILS technique is that measuring can be performed rapidly and inexpensively. The turnaround time for measurements is reckoned in days, instead of months. It is feasible to relatively date artifacts while the fieldwork is STILL UNDERWAY. This capability is a boon to excavators and enables some mid-course corrections of research strategy to be made.
The Future

Any powerful dating technique, like ILS, is not just an adjunct to archaeological research, rather it itself is capable of dictating what an archaeologist should be investigating. Once a researcher grasps this archaeometric method, it is difficult to let go of it, reminding us of the proverbial person holding on for dear life to a tiger’s tail.

During 2012 in Colbert County, Alabama, colleagues and I visited a site where a rare Early Stage Cumberland point had been recovered by local resident, Charles Moore (see Figure 1). It had lain upon the surface of a field that had been cultivated since the 19th century. We picked up some flaked stone tool fragments and large flakes from this spot and sent them to Prof. Charles McNutt at Memphis, TN for ILS analysis. Their light readings averaged approximately 86,000 units. This result, when compared to averaged readings for Clovis artifacts in Colbert County (approx. 75,000 light units), suggests that the site where the Early Stage Cumberland had been found is 15,000 calendar years old – making it potentially the oldest archaeological site ever identified in the United States. Certainly such an age corroborates the postulated antiquity of Charles Moore’s Cumberland point – somewhere between 15,000 and 16,000 calendar years.

Knowing what we do about the possible antiquity of this archaeological site in Colbert County, is there anyone here who would refrain from investigating it?? Any red-blooded archaeologist would bow to such demanding data and excavate.

This need to make a trip to Colbert County is given impetus by the discovery of a fragmentary El Joboid point made of Ft. Payne chert (see Figure 2). Its finds spot lies within a few miles of where the Charles Moore Early Stage Cumberland point came to light. Amazing to relate, the averaged light value for this single projectile point is 91,464. Comparing this finding to light values of Clovis points from the immediate region, we learn that its relative age is almost 16,000 calendar years (15,860 years)! In other writings I hypothesized that thick, medially-ridged El Joboid points gave rise to the Cumberland Fluted Point Tradition approximately 16,000 years ago when a major biotic ecotone was located in northern Alabama. The ILS dating technique indicates to us that this deduction, as bold as it may seem, is not wide of the mark!

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April 14, 2019
References Cited

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![Figures 1 and 2. Left, Early Stage Cumberland point found by Charles Moore at a site in Colbert Co., AL; right, basal fragment of an El Joboid point from a site in Colbert Co. Actual sizes.](image-url)