



Figure 1. Corner detail of games table (Metropolitan Museum of Art/ADA 66.170) showing anthemions, circles, stars and Greek key.

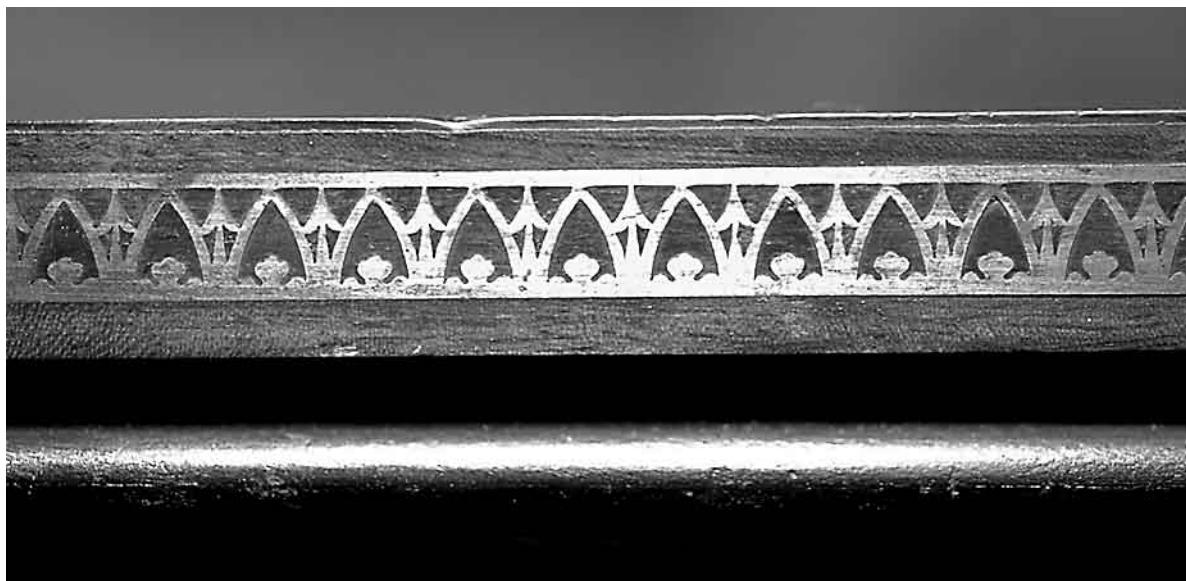


Figure 2

Laser Reproduction of Brass/Wood Inlay in Furniture by Charles Honoré Lannuier

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THE FURNITURE OF CHARLES HONORÉ Lannuier, an early 19th-century New York cabinetmaker, certainly represents one of the pinnacles of furniture craftsmanship on this continent. Those of us lucky enough to have worked with his pieces have been treated to often dazzling displays of intricate joinery, frighteningly crisp carving and decorative details whose execution somewhat boggles the mind, even in our own era of high technology. Take for example, the complex tapered, sliding dovetails—a luthier's joint—he used for leg attachments on many of his pier and games tables. With Lannuier's furniture there is always some exquisitely executed detail lurking for the observant eye, especially in passages where a much simpler or expedient technique would have sufficed for most artisans.

One aspect of his decorative repertoire that has both delighted and frustrated conservators for years are the elaborate wood and brass inlay bands prevalent on his furniture. (figs. 1 and 2) These elements consist of a brass background, either in the form of a strip or band, or as a separate "unit" (star or circle, e.g.), with an infill of wood. Such work was certainly not unique to Lannuier, and can be seen on many pieces from other makers, especially from New York and Boston shops. Examination of this work shows it was done via die stamping, in a single-repeat scenario (i.e. one stamping at a time, with the strip subsequently moved a precise jiggled amount, followed by another stamping, etc.), and that the wood was inserted under great pressure, as evidenced by the linear distortion of grain lines and crushing of vessels. Ingenuity, as well as patience could achieve any number or variations on a rather small vocabulary of shapes, by stacking, inverting, repeating, etc. Noteworthy is the fact that similar

(or exact) inlay elements or units can be seen on the work of diverse artisans, strongly suggesting a common source for much of this work. (fig. 3)

Restoration of Lost Inlay

Because this brass/wood inlay plays such a prominent role in the decorative scheme of Lannuier's work, replacement of missing portions has been a vexing problem for conservators and restorers in the past. Often sections are lost *in toto*, which at least affords the conservator the ability to manufacture a complete strip or unit by the method of their choosing. These have included everything from the simple (painting/gilding on wood) to the sophisticated (photo-etching), to the endurance testing (cutting with jewelers saws). These methods all have their merits and situations where they may indeed be the best method to use. Some inlay has also been recreated in the past by the use of dies made specially for the purpose. Such a method would obviously achieve the finest, most historically accurate results, but with the added caveat that future differentiation of materials of similar fabrication techniques may be difficult.



Figure 3. Stretcher base of pier table, New York origin (private collection, New York City). Note the use of the same anthemion form as in Fig. 1, this time repeated and inverted.

Perhaps the greatest challenge in restoration of brass/wood inlay strips is the failure of the substrate wood/brass glue joint only (affectionately known to a few as a “zipper blow-out”), where the wood infills only remain. As the wood/wood joint is inherently stronger, in a strong outward pull, the brass can pull off leaving the wood fills behind. Replacing the brass only, to fit precisely around the existing wood is a task that would certainly try the patience of Job.

This paper will describe one method that was employed to replace missing brass/wood inlay on a number of pieces by Lannuier, both at the Metropolitan Museum of Art, and in private collections in the New York area. It is the technique of computer-controlled (CNC) laser milling, a technique long employed for precision fabrication, but relatively unused by the conservation community.

I feel that there is a wealth of applications possible to our discipline in the field of laser milling technology. A primer on laser technology and theory is way beyond the scope of this paper. Learning a few basic concepts, however, will help anyone who might want to employ this technology for conservation purposes at least begin to look in the right places and ask intelligent questions.¹ “Laser” is an acronym for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation. Simply put, a laser is a producer of a narrow beam of monochromatic, coherent light. “Coherence” means that the light waves are all in phase with one another. There is also a very small divergence or “spreading out” of the beam; a common figure would be a divergence angle of less than one milliradian (1 meter in a kilometer). While there are many types of lasers, the two of greatest importance for the types of machining used here are gas (CO₂) and solid-state (neodymium-YAG). The light emitted from these materials, excited by a source, has different wavelength and peak energy characteristics, which can be effectively utilized in differing processes.

CO₂ vs. YAG Lasers

We've all seen the somewhat tacky laser-engraved wooden plaques and nameplates for desks, showing with bravado the laser's ability to cut with incredible detail, in intricate patterns (the cut line of a CNC CO₂ laser can be around .15 mm). These are executed with a CO₂ laser, probably the most

versatile laser for most machining purposes. CO₂ gas excited by an external light source emits a wavelength of 9-11 μm (micrometers), and when focused is used primarily for cutting and welding. The relatively low cost of simple CNC milling set-ups with CO₂ lasers has led to a proliferation of small laser milling businesses, most of which seem to deal with the “Great Hole In One!” type of aforementioned plaques. When looking for a contractor of this sort to execute our inlays, I was often met with the reply “you can't cut brass that intricately with the laser.” With further research I discovered this was both true and false. Avoiding these sorts of machinists would be to one's advantage; later in the paper there will be some source addresses from which you can find more technically-oriented laser machinists.

CO₂ lasers emit a beam with a wavelength of around 10 μm , a frequency band which most organic materials absorb quite readily. This means that the material under the beam will get quite hot, and in our use, be vaporized in a small, closely controlled area. Wood can quite easily and efficiently be cut with the CO₂ laser. The problem with brass/wood inlays is the reflectance of metal, which can exceed 90% at the 10 μm wavelength of CO₂. The laser beam will simply bounce off of the metal surface. A laser that emits in a wavelength that most metals absorb was needed.

Fortunately, another common form of laser, the Neodymium Yttrium Aluminum Garnet (known as “Nd-YAG”, or simply “YAG”) fills the bill. These lasers fall into the category of solid-state lasers, in which a crystal or glass matrix is excited by an external light source. Neodymium atoms are introduced as an impurity into this matrix host, at about a 1% concentration. A very common host is YAG (Y₃Al₅O₁₂), which is a synthetic crystal with garnet-like properties. Neodymium has roughly the same ion-size as Yttrium, and can be substituted in the matrix during fabrication. The light emission from the YAG laser has a wavelength of 1.064 μm , about a tenth that of CO₂. Most metals are fair to good absorbers at this wavelength.

The foreman of the machine shop who did our work informed me that he could cut most any metal, but with differing success; depending on the metals reflectance properties, an ultimate

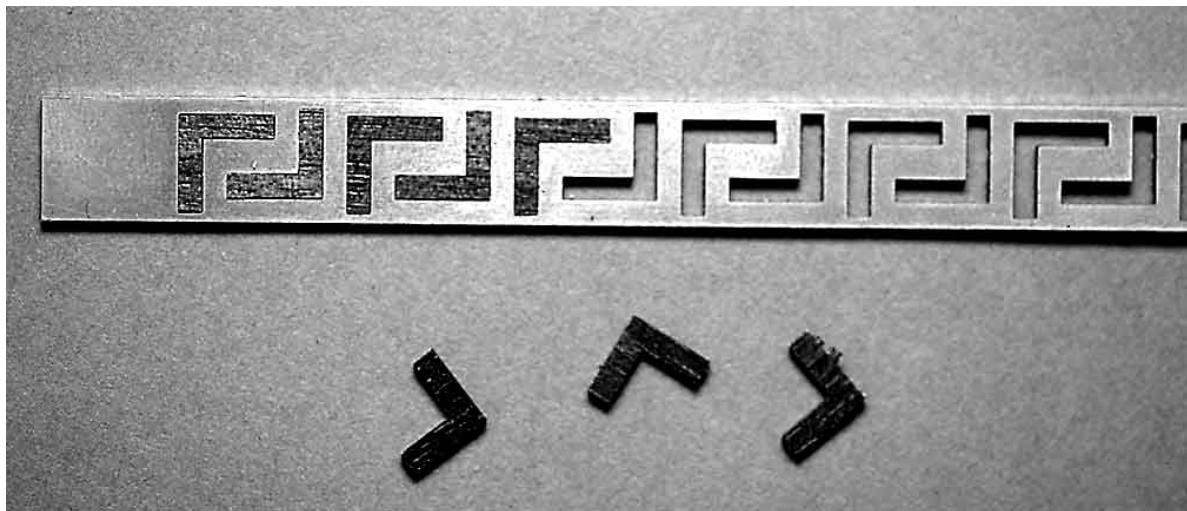


Figure 4. Greek key pattern, beginning to load wooden inlays.

thickness of cut would be reached. The reliable cut depth for brass was on the order of 6 mm, well beyond what was needed for our inlay (about .9 mm). YAG lasers are often operated in a carefully controlled and rapidly repeated pulse, and can achieve a high, but short duration, peak power. Metal such as brass does not suffer from any appreciable distortion due to heat at this thickness (as we were told to expect by some), as the metal itself seems to act as an efficient heat sink for the heat generated during the process. We certainly saw no problems due to excessive heat in the inlay strips we received from the machinists—no warpage or change in dimension at all.

Obviously, having both lasers is essential for a shop to carry out this sort of work; the two beautifully complement each other for the necessary processes. Needless to say it should be a prerequisite question in one's search for a machinist to avoid a lot of subcontracting and potential problems.

The Machining Process

For milling procedures, the lasers are computer controlled, driving them across an X-Y axis according to software input given by the operator.² The computer operates on some variant of CAD program, depending on the setup. Various means can be used to input the design into the CAD program, such as scanning a portion of the original (probably the easiest and most reliable), scanning a drawing, or construction of the design on the computer itself. For reasons that were never made clear to us, the machinist we used preferred to work with measured drawings, and to "construct"

the design on his CAD program. There is the matter of correcting for the .15 mm cut width, which must be moved to the inside of the line on the brass cuts, and to the outside of the wood infill to achieve a perfect fit. How perfect one needs the fit to be is a somewhat personal issue (.3 mm hardly being the end of the world); this is the source of a lot of time spent on fine tuning the design.

One reason to work toward a perfect fit has a rationale beyond pure aesthetics. The laser can be manipulated to produce a cut on a very slight angle, by taking advantage of the focusing distance from the cut surface. The practical use of this is to produce a very slight dovetail, with the wood infill being somewhat wider at its outside surface than its inner one. Since the wood will naturally form a better bond to the underlying structure, this "dovetail" will serve to help hold the metal on should its glue joint ever fail. This is a structural improvement over the original, and yet another way to differentiate the modern from the old in the future (there are others, which will be discussed below). It should be noted that the "dovetail" cutting will necessitate there being a "front" and "back" to the inlay—potentially a problem for asymmetric patterns such as the Greek key. (fig. 4)

We found it expedient to allow the machinist to provide the sized metal strips, as he could easily produce them himself. The infill wood is more important as to color, grain, etc., and should be provided by the conservator. With the raw material in hand the operator executes test cuts, then proceeds to cut endless repeats of the pattern. With

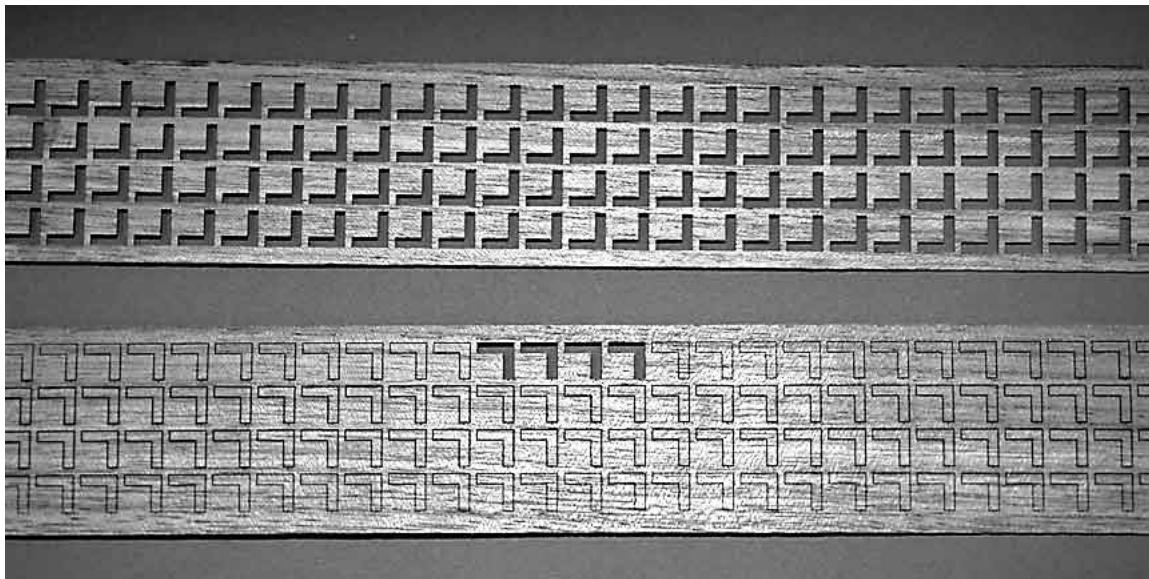


Figure 5. Repeated cuts for Greek key inlay.

fine adjustment of depth (and assuming one's material is evenly thicknessed) the laser can cut a whole sheet of wood infills, with but a whisper of wood left to hold the pieces in place, which can then be "popped out." (fig. 5) The same cuts are made in the brass, only here they are done all the way through the material. Very small bits are cut completely through in the wood as well, as separating them from the sheet would be difficult. The size potential (small) and accuracy of the cut can only be described fully as "scary". This is what the materials look like as received from the machinist.

(fig. 6) Next comes many hours of monotonous Walkman-style work as the bits are loaded into their cavities. (figs. 7 and 8) With a good machined fit, they are pressed in with light pressure and hold very well. The strips can be bent very easily once loaded, provided matching bending cauls are used to prevent the strip from kinking in an uneven bend, or twisting out of plane.

The brass should be cleaned of any oil/grease beforehand, and preferably scored on its underside for tooth in gluing. Practical experience has shown



Figure 6. "Zig-Zag" for table in figure 1. The dime gives an idea of the small scale of cut possible with laser milling (this is by no means the limit).

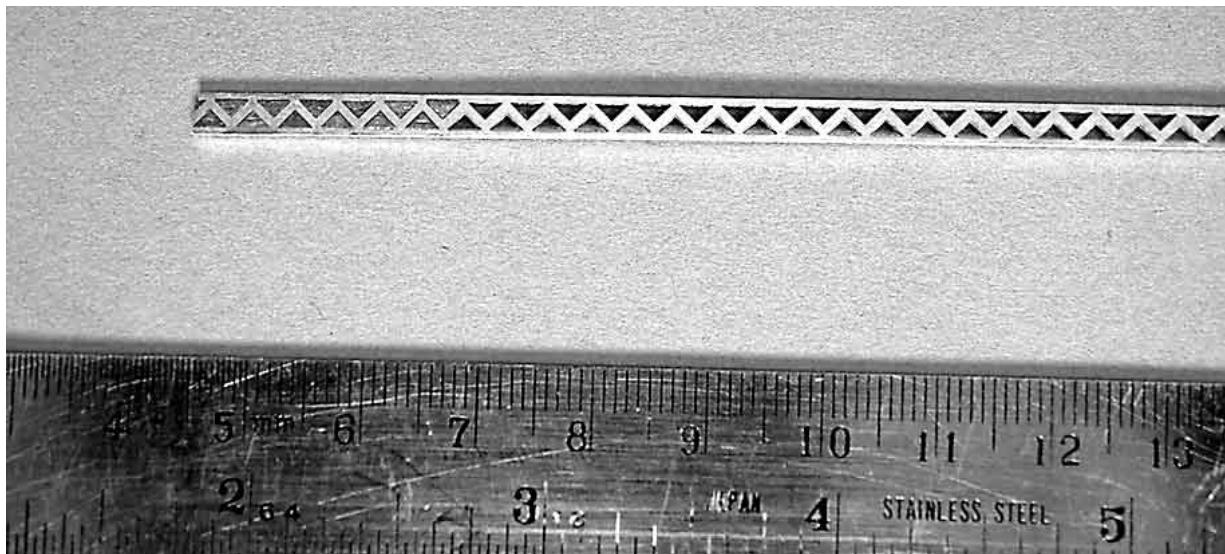


Figure 7. Partially loaded Zig-Zag. (NB: Walkman required, Phillip Glass recommended.)

that *Liquid Fish Glue*, sold by Lee Valley Tools in Ottawa, Canada,³ has exceptional properties of tack and flexibility for gluing metal inlay strips (of all sorts). As an aside, it is interesting to note that most all of the inlay strips on Lannuier's furniture is carefully mitered at the corners, with the patterns continuing seamlessly.

Pros and Cons of Laser Cutting

The biggest benefit of laser machine cutting is the ability to achieve an incredible and consistent level of exactitude, with little regard for the size or complexity of the pattern. Patterns that would be unthinkable in other methods due to their fineness or complexity can be simple with lasers. In addition, laser milling is well adapted to the inclusion of wood into the inlay. Photo etching, which is the standard "traditional" method to use for restoration, cannot incorporate wood into the fill, and must resort to using waxes or colored resins—a uniform color field. Anyone who has spent a bit of time looking closely at Lannuier's furniture will attest to the fact that the wood character of the infills is both discernible and important. Also a plus, the inlay will always be distinguishable from the original (or restoration die-cut) by the nature of its cut. The laser cut edge of the brass is somewhat "pebbly" and amorphous, while the die-stamping produces a striated shear cutting, with occasional tearing of the metal. Also, the wood structure has none of the crushed characteristics, with distorted grain and flattened vessels (in section) that the

original does. Cuts made by a jeweler's saw make an obviously repetitive striation, different from both of the above. And, as mentioned above, the dovetail cut, if employed, is a dead giveaway.

The biggest drawback is obviously the cost. It is expensive. Very expensive. But so is Lannuier's furniture. And the inlay is incredibly prominent on the pieces, possibly justifying a "by any means" approach. If the cost is justifiable on a healthy six-figure valued piece, it probably isn't on any of the more nondescript pieces that incorporate similar inlays. And for such cases, simpler methods are arguably better suited. However, as most of the inlay patterns are somewhat standardized,



Figure 8. Parts, and loaded anthemion.

it is conceivable that eventually most of it will be "programmed" for laser milling, thus making subsequent runs cheaper for later comers, provided a little sharing is involved. There is also the very real possibility that this technology will become cheaper if it proliferates.

The real purpose of this paper was not to propagandize the merits of laser machining of furniture inlay (which are obviously not possible for everyone), but simply to make people aware of its existence as a milling technique. It is my hope that by learning of the availability of this type of machining, creative types will perhaps unearth other, possibly more cost-effective solutions to treatment problems in our field. The exact machining of very complex shapes, perhaps losses that are digitally scanned, would be a conceivable use of laser milling, were the cost to become low enough in the future. Perhaps taking advantage of the laser's ability to cut to very precise depths could be exploited to reproduce differing surface textures in various materials. There is a world of possibilities to be explored.

Finding a Machinist

Undoubtedly, the best source for information on laser machine shops are the pages of: *Laser Focus World Buyers Guide* (PO Box 989, Westford, MA 01886 (508) 692-0700), an industry publication, with listings of various laser-related services (leasing, repair, system design, etc.), including "Laser Job Shops". A wide assortment of domestic as well as foreign machinists are listed.

Notes

1. Info on wavelengths, etc. was taken from: Hecht, *Laser Guide Book*: 1992, Tab Books, Blue Ridge Summit, PA
2. Description of machining process as given by laser operator of Micrometrics Ltd., UK
3. High Tack Fish Glue. Available from: Lee Valley Tools Ltd., 1080 Morrison Dr., Ottawa, Ontario, K2H 8K7 Canada.