Trishanku: a frugal collimation tester for less than 1 cent

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Abstract: *Trishanku* (त्रिशंकु) is an inexpensive collimation tester for optical alignment. It uses a set of four asymmetric holes, resembling *trishanku* (or *crux* constellation). This tool offers freedom to perform a random orientation collimation without a need for precision machined posts on optical tables. The asymmetry of the holes allows for an easy perpendicularity check and helps in collimating beams at any random angles which is not possible by existing tools. *Trishanku* can be used to collimate coherent as well as incoherent beams. I make it on a blackened aluminum foil with the help of general office supplies. Costing less than 1 cent, this tool can match the performance of any expensive collimation tester in an optics lab. I have been using this tool for more than 4 years for successfully aligning sophisticated optical microscopes.

1. Introduction

Collimation tester is an important tool in any optics research lab. It is widely used to test the collimation of an expanded laser beam which is crucial in holography, imaging and microscopy related applications. Shear plates are the most popular tool for this purpose. They are attractive due to their ability to test collimation in a tight space and are very precise due to their interferometric working principle. However, they only work for coherent beams and are unsuitable for any multimode/cheaper/in-coherent lasers or laser diodes.

Incoherent laser beams can be collimated with a set of precisely manufactured posts with two holes[1]. These posts are usually precision manufactured with 1 mm diameter holes placed a few millimeters apart. The first post in the expanded beam path samples two beamlets which continue to propagate and fall on the second identical post which acts as a tester. Any convergence or divergence in the original beam shows up as unmatched beamlet spots on the tester post. If perfectly collimated, the two beamlets symmetrically pass through two holes on the test post. However, this approach for collimation testing has multiple drawbacks. First, they require precision manufacturing to meet the tolerance requirements for obtaining reliable collimation and hence are not cheap. Moreover, it is assumed that posts are perfectly vertical and perpendicular to the incoming beam, but it may not always be true. This leads to the second concern that posts may bend over time or may tilt depending on optical table finish which will lead to error in beam convergence or divergence testing. Relatedly, these posts work only for horizontal beam alignment and are limited to optical tables. Many times optical beams need to get collimated in odd orientations and not on an optical table. Thus, there are no tools which can readily be used for testing collimation in a variety of scenarios.

Here, I describe *trishanku* which is an inexpensive collimation tester which resolves all the drawbacks listed above. *Trishanku* costs less than 1 cent and requires general office supplies to manufacture it.

2. Working principle

Let us tackle the aforementioned issues with a creative thought process. We will divide our problem into different segments and tackle each segment to converge to a final solution.

2.1 An inexpensive precision manufacturing of holes: Traditional two-hole posts described above are precision manufactured in a machine shop. The distance between two holes and their position is crucial. How can we make this fabrication process inexpensive while maintaining the same precision? We can do this by learning from the centuries old book binding process. Or, for modern times, from the spiral binding process. A stack of papers are punched in one shot to produce a precisely matched hole on each sheet in the stack. This precision is well within the order of a few tens of microns. We can therefore take this approach to manufacture matched holes in our case. I used one push pin (from any office supplies store) to punch holes in a blackened aluminum foil (blackened to stop random reflections of laser beam during alignment).

2.2 Non-dependence on optical table or flat surfaces: Traditional two-hole posts rely on perfectly flat surfaces for accuracy. The flatness of the base plate, on which the posts are mounted, is also crucial. Thus, they are limited to horizontal beam alignment. A vertical or oblique angle beam cannot be collimated faithfully. How can we avoid this dependence and make the collimation test usable for random angle beams? We can do this only if there is a way to know when the tool surface orientation with respect to the propagating beam. This is not possible with a two-hole arrangement as the distance between two beamlets on the detector post varies for two reasons: a) convergence/divergence in the optical beam, and b) tilt in the detector post itself. We need to isolate these two factors. We can do this by having more than two, non-collinear holes. In this case a tilt in the tool shows up as an asymmetric expansion / contraction of the beamlets on the detector post. Thus, a non-collinear arrangement of three or more holes will enable a solution to the dependence on a flat horizontal surface. Since the beamlets passing through these holes appear like stars, I wanted them to resemble a constellation in appearance. This is where *trishanku* (or *crux* constellation) with only four stars came up as the best choice. *Trishanku* is the *Sanskrit* name for the *crux* constellation and has a beautiful mythological story associated with it.

3. Methods

In this section, a step-by-step method to fabricate a *trishanku* collimation tester is described. Figure 1 shows a pictorial display of the steps.

a. A scissor was used to cut a matte black aluminum foil (BKF12, Thorlabs) into two square pieces of 50 mm × 50 mm size. Alternatively, a general purpose kitchen aluminum foil (preferably the thickest one available) could be used where its surface could be blackened by exposing it to the visible part of flame, from a candle or a lighter, to form a uniform soot coating. Depending on the application, a much larger (or smaller) square or rectangular piece could also be used.
b. Two aluminum foil pieces were stacked on top of a cardboard box (or a craft foam/styrofoam block) and a demagnified print of the *trishanku* (crux constellation)[2] was placed on top of this arrangement. This print was scaled to contain all the stars in 5-10 mm diameter as per the collimated beam aperture requirements.
c. A push pin was used to punch/pierce holes along the four stars of *trishanku*.

d. The top paper was removed and remaining two aluminum foil pieces below it were recovered as the two-piece *trishanku* collimation tester.
e. If desirable, the pieces were stuck to popsicle sticks to reduce direct handling which may lead to unintentional folds. The stick also helps in easy positioning of the pieces in a random orientation as required during alignment. Alternatively, these pieces were cut to fit 1″ or 2″ optical mount to go directly in a post-holder and on top of the optical table.

Table 1 in the supplementary information section shows a list of required and optional items.

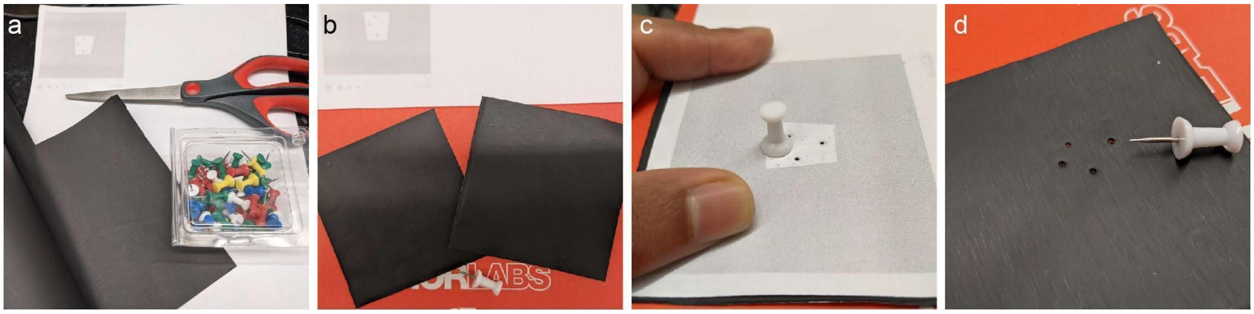

Fig. 1: Fabrication process for a *trishanku* collimation tester: (a) parts-list, (b) two cut-pieces of aluminum foil on cardboard box, (c) a pin punched through the relative positions of stars and (d) resultant trishanku collimation tester - the second layer is hidden beneath the top one.

Using *trishanku* is straight forward. One piece is placed right next to the trailing optical lens beyond which a collimated beam is expected. This creates four beamlets which continue to travel along the original beam path. The second piece of *trishanku* is placed at some distance (more than 100 mm away) in this beamlet's path. An asymmetric beamlet's position with respect to the actual holes in the second piece suggests that the second piece is not normal to the beamlet's path. This is corrected till the beamlets become perfectly symmetric. Now, a converging or diverging aspect in the original beam can be easily accessed by observing if the beamlets are nearer (down-scaled) or farther (up-scaled) in comparison to the holes, respectively.

4. Discussion

Trishanku is an inexpensive collimation tester which can be readily made with general office supplies. Any kinks or folds, which may affect the collimation results adversely, are easily visible on *trishanku*. These can be corrected by pressing it between books/flat metal blocks. It can be easily mounted in SM1 or SM2 compatible thorlabs mirror mounts enhancing its usability base (**see Fig. 2**). With a popsicle stick mounted assembly, it can be used handheld at any random angles which are not restricted to horizontal direction.

The quality of collimation obtained with *trishanku* is on par with a shear plate. The biggest advantage is that unlike shear plates, *trishanku* can be used for incoherent light sources. *Trishanku* has been successfully used for aligning advanced single objective lightsheet microscopes over the past multiple years.[3-5] *Trishanku* is also an integral part of the alignment protocol for the upcoming crossbill microscopy project.[6]

Although presented as a four-hole arrangement and with a specific template, it is not essential to have four holes. Any arrangement of three or more non-collinear holes will work. An asymmetry in the hole position is helpful to enable easy orientation.

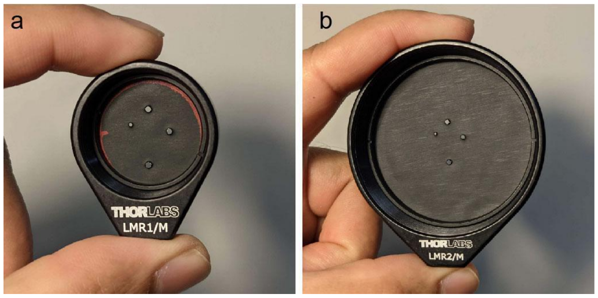

Fig. 2: *Trishanku* collimation tester is fully compatible with traditional post enabled optics mounting options. (a) mounted as 1″ optics, and (b) mounted as 2″ optics.

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6. Crossbill (A single objective light-sheet microscope) https://sites.google.com/view/crossbill

Supplementary Information

Table 1: Parts list for fabricating *trishanku* collimator

Essential items	
	size/quantity
Aluminum foil (Blackened) (BKF12, Thorlabs)	25 mm × 25 mm (or larger) - 2 pcs.
Push pin	1 pcs.
Accessories and optional items	
Office scissors	1
Popsicle sticks	2
Scotch tape	1
Candle/Lighter (for soot)	1
Satin pin/needle	1
Craft foam/cardboard box	25 mm × 25 mm (or larger) - 1 pc

Cost of *trishanku* collimation tester: Commercial blackened aluminum foil from thorlabs costs $32.5 for 305 mm × 15.2 m. We typically need less than 50 mm × 100 mm size foil to fabricate *trishanku*. So, effective cost for one *trishanku* collimation tester = 0.35 ¢. This cost does not include the office supplies required in Table 1. If not accessible, they can easily be borrowed from a neighboring office or household, and so can be a small piece of kitchen aluminium foil. The idea of *trishanku* is not to debate or boast about actual price but to show that an innovative thought process can help create very useful tools at no cost. The world needs more frugal solutions to make an impact.