Free surfaces of liquids in Interferometric Methods:
Application to Split Corner Cubes

Jean-Louis Oneto[1], Jean Gaignebet[2]

Abstract:
A method to adjust and control split corner cubes down to a sub arc-second accuracy is presented, based on an interferometric setup involving use of free-surface of liquids. Such a split corner cube can then be used as a convenient method to adjust parallelism of emission/reception optical axis in laser ranging stations.

Introduction:
The task of aligning the parallelism of emission/reception axis in a laser ranging station can be made a lot easier with the help of a split corner cube system. If the design of such a tool avoids thermal and mechanical drifts, it is possible to reach an accuracy better than one arc-second, using the free surface of a liquid as a reference plane in an interferometric test method. The observed stability of the described device is also of the arc-second order over several months.

Description of apparatus: (Figure 1)

The split corner cube uses 3 rods which support two plates: at one end a roof-prism is directly fixed on the plate (Figure 2), while at the other end a right-angle prism rests on a mount with 2 sets of adjusting screws: 2 screws for coarse adjustment (0.5 mm/turn), and 2 screws for fine adjustment, still 0.5 mm/turn, but acting through 1÷50 ratio levers (Figure 3). This gives a resolution better than 1' for 10° on the coarse screws, and around 1" for 10° on the fine screws.

In order to minimize the thermal drifts, most of the structure is built in Invar (near zero-dilatation stainless steel), in particular the rods and levers. Furthermore, multilayer aluminized Mylar and foam material is heavily used to keep thermal gradients as low as possible (Figure 4, Figure 5, Figure 6, Figure 7).

Figure 1: Overall view of the split corner cube

[1] Observatoire de la Côte d'Azur/CERGA/CNRS, Avenue Copernic, 06130 Grasse, *France - oneto@obs-azur.fr*
[2] (retired from) Observatoire de la Côte d'Azur, Avenue Copernic, 06130 Grasse, *France - gaignebet@obs-azur.fr*

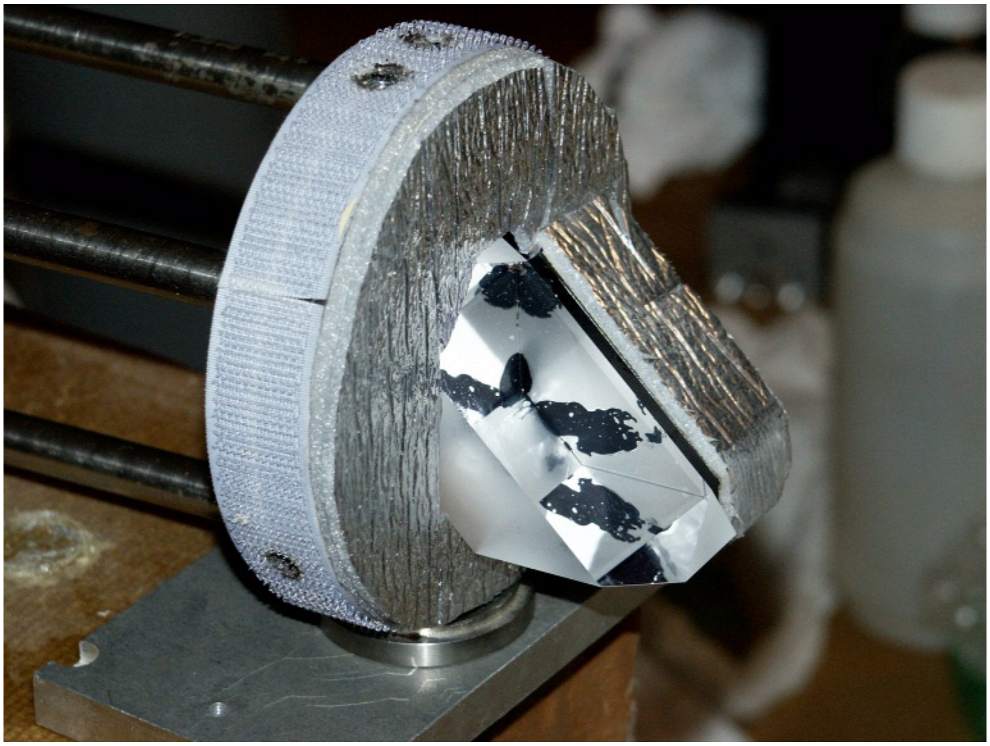

Figure 2: Roof-prism on plate at rods end.

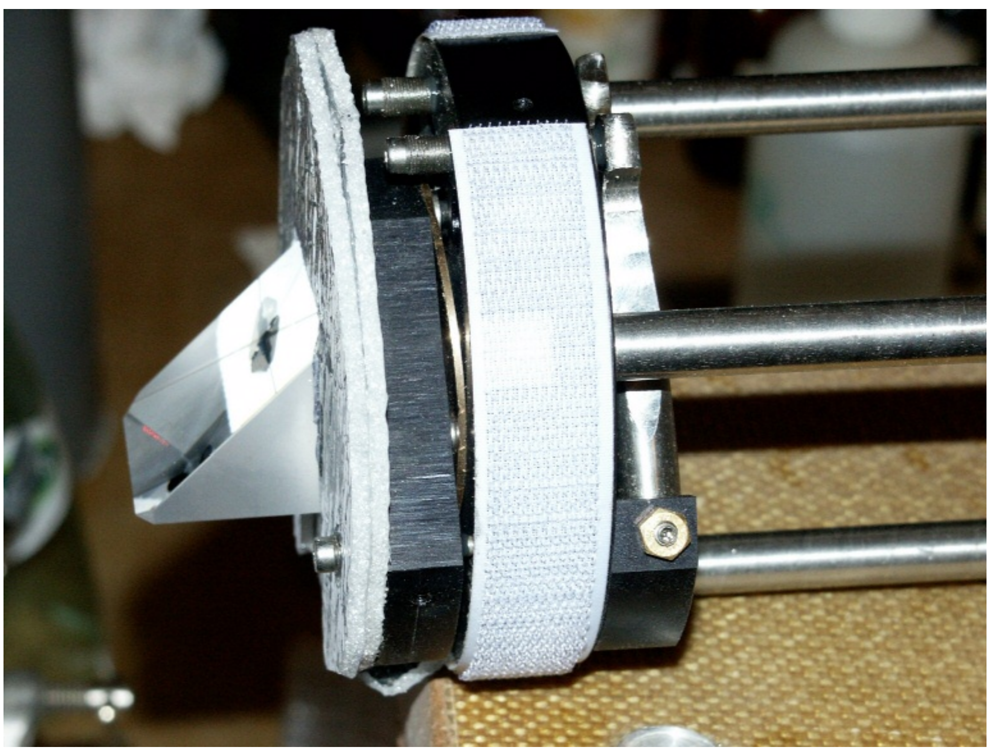

Figure 3: Right-angle prism on its adjustable mount

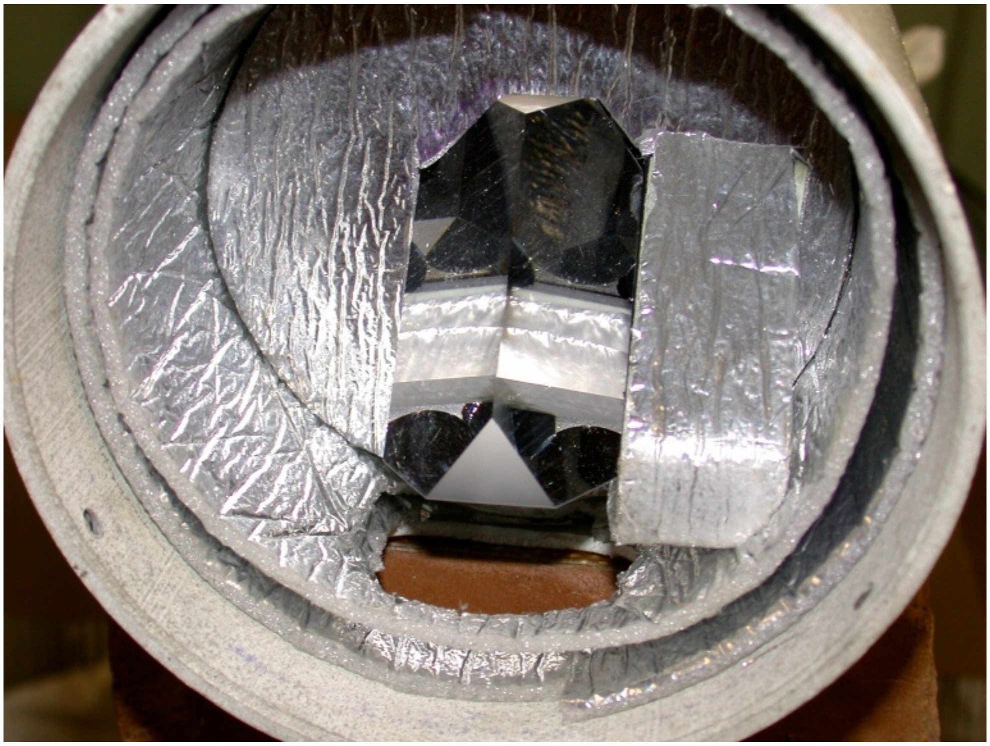

Figure 4: Thermal insulation of the roof-prism

Figure 5: Thermal insulation of the right-angle prism and its adjusting mount

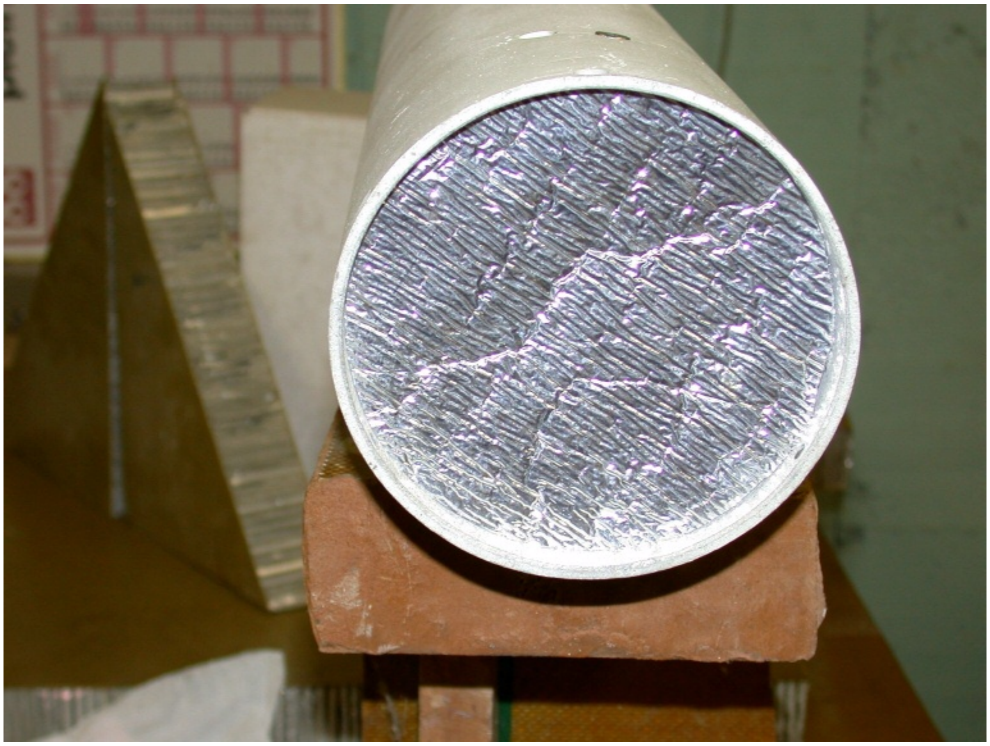

Figure 6: Thermal insulation (last stage)

Figure 7: Thermal insulation and protection

Experimental setup for alignment of the split corner cube: (Figure 8 and Figure 9)

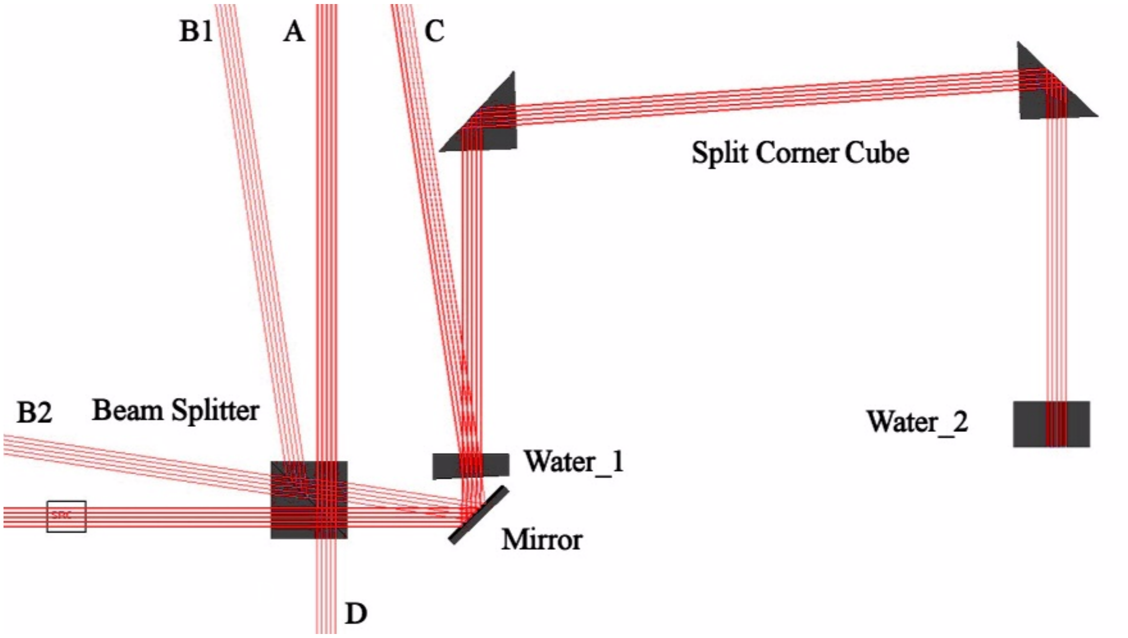

Figure 8: Schematic of the alignment setup

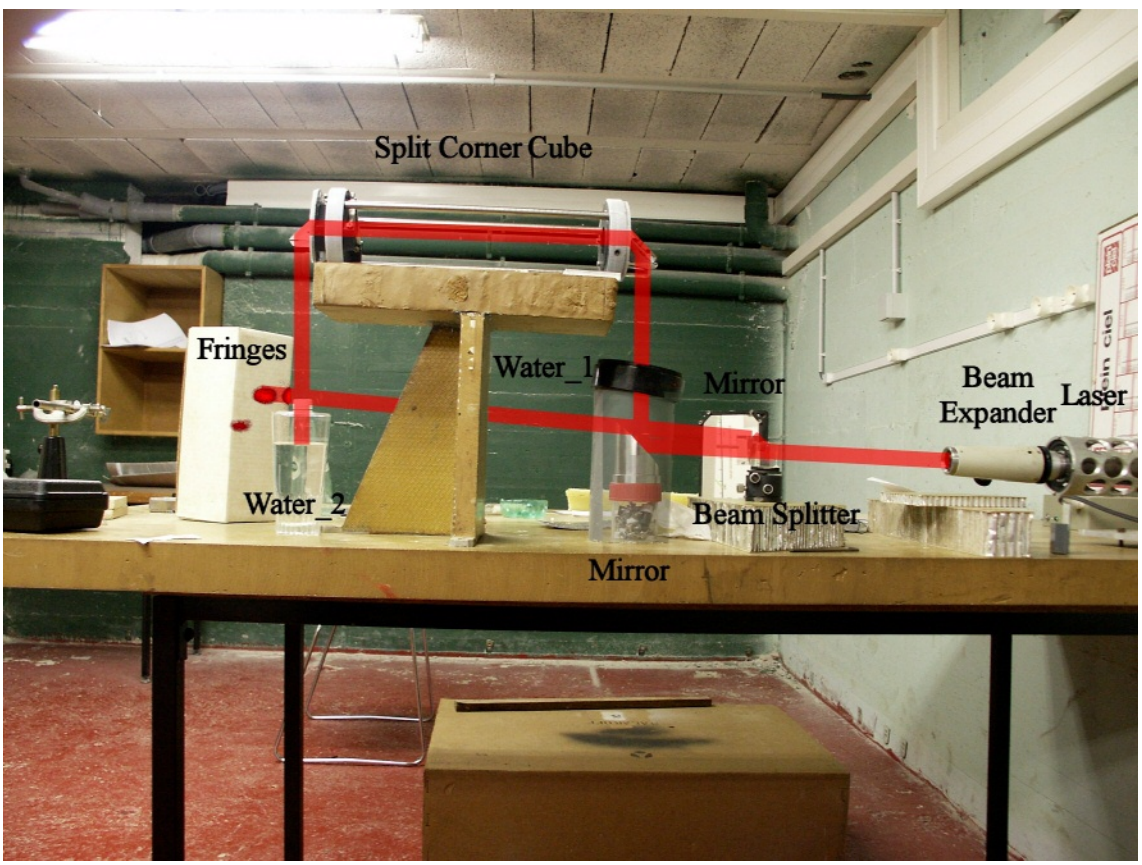

Figure 9: Experimental alignment setup

The laser beam is first expanded to a convenient (≈ 25 mm) diameter, then it goes through a beam splitter. The 45° mirror reflects it in a near vertical direction such that the (partial) reflection on the free surface of Water_1 is autocollimated with the incident beam. This is only needed to stay in the small field of the split corner cube, but otherwise the quality of this autocollimation has no influence on the precision of the method.
Most of the beam goes through the water, then the split corner cube. The beam (partly) reflected by the Water_2 goes back through the split corner cube and interferes with the beam reflected by the Water_2. The beam splitter separates them from the incoming beam, allowing easy observation of the fringes (Figure 10). Since the meniscus of liquid against the wall of the dish curves the free surface, the part used must be taken several centimeters apart from the edges.
When the split corner cube is perfectly aligned, the fringes are centered Newton rings. The diameter and spacing of the rings are irrelevant since they only depend on the quality of the wavefront of the laser beam. The quality of the alignment is given by the symmetry of the rings.
Of course, to observe interference fringes between two free surfaces of water, it is imperative to keep the whole setup perfectly quiet, the smallest vibrations, sounds or microseisms blur them, without even speaking of waves! That can make the whole procedure rather stressing, but you must keep in mind that getting upset can only make things worse… That is why this should be called "Zen Interferometry"! Another condition for having fringes is obviously that the coherence length of the laser used must be greater than the path difference (round trip between the 2 water surfaces). Since the two reflections from the free surfaces are basically of same intensity, the contrast of the fringes is quite good. The spurious reflections on the entrance/exit faces of both prisms attenuate the wavefront from Water_2. This can be partially compensated by using a different liquid with a higher optical index for this free surface. Experimentation using oil was tried, but the gain was hardly noticeable. On the Figure 8, the beam A corresponds to the fringes, B is the reflection from the bottom window of Water_1, C is the reflection on bottom of Water_1 of the beam from the surface of Water_2, and D is the spare beam from the beam splitter. In fact, few of the spurious reflections are represented here and all the reflections on the entrance/exit faces of prisms and beam splitter were omitted for clarity.

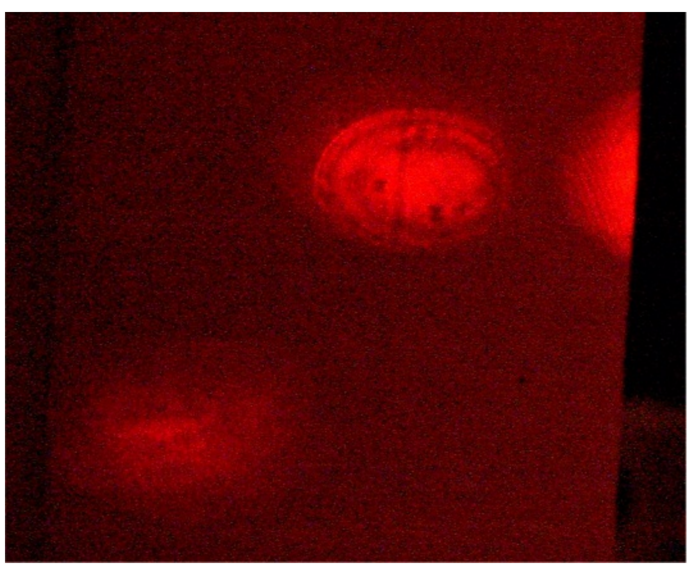

Figure 10: Detail of fringes

Applications:

1. **Emission/Reception parallelism (Figure 11)**

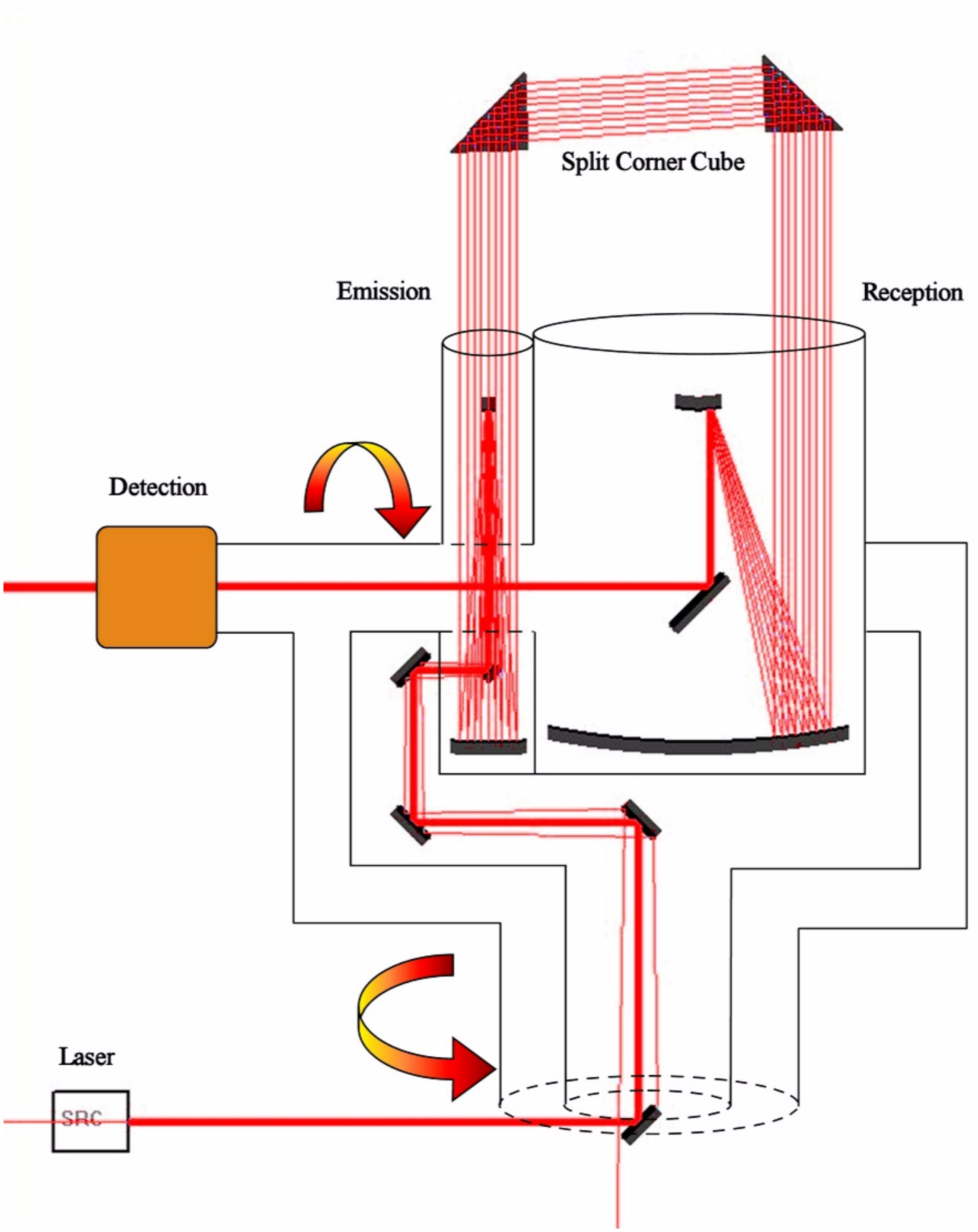

Figure 11: Emission/Reception parallelism

2. Control of a telescope mount and zero of Alt encoder (Figure 12)

Autocollimation on the free surface of a liquid through a Split Corner Cube gives a vertical reference which can be used to control the setup of Azimuth axis of a mount, and/or defines the zero of the Alt encoder. This is useful in case where the movements of mount are limited, e.g. making half-turns on Alt axis impossible.

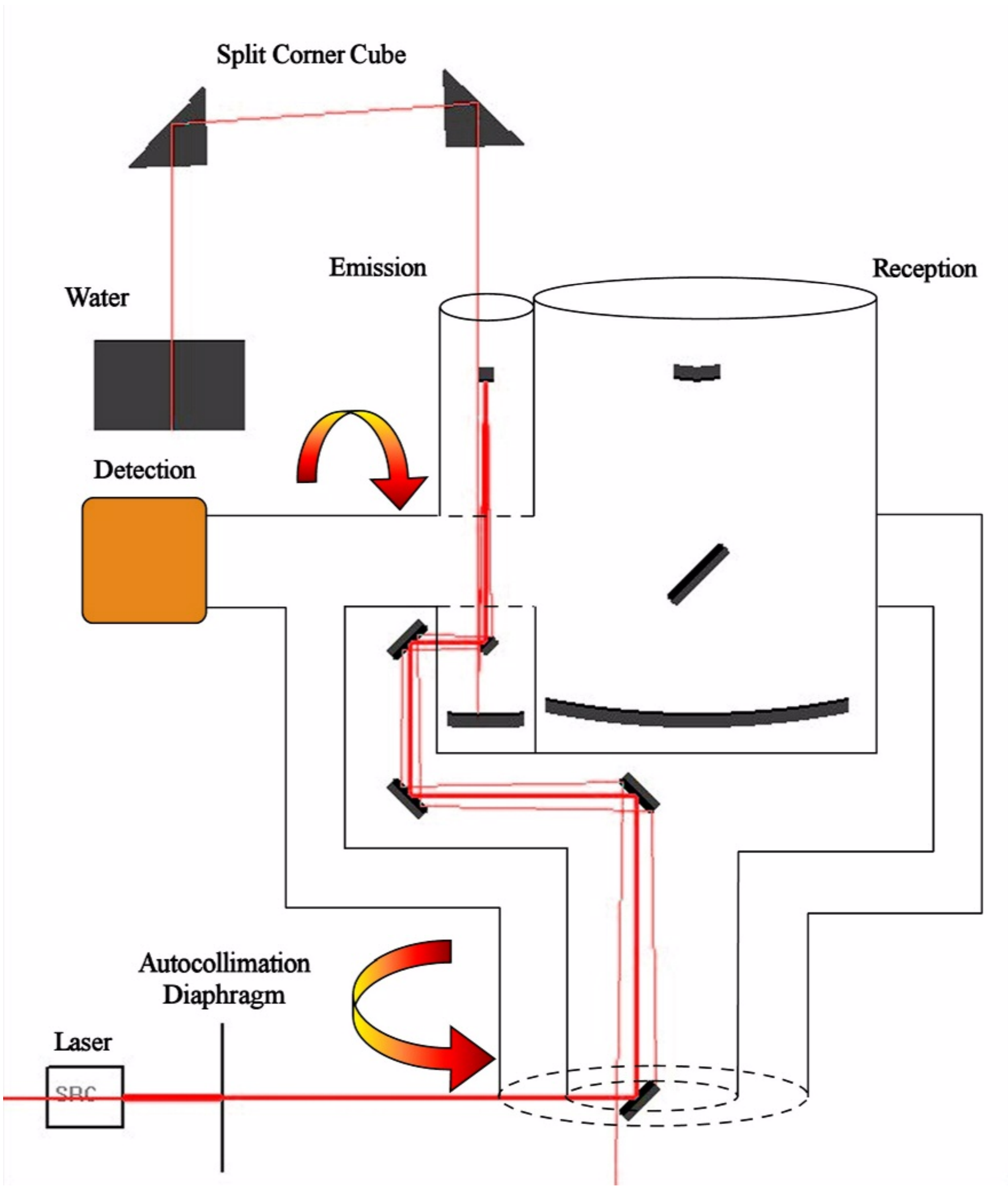

Figure 12: Control of a mount and zero of the Alt encoder

Conclusion:

- The use of an interferometric method to align a split corner cube, allows to reach an accuracy of one arc-second, which correspond to 1 mm at 200 m. That would be very difficult if not impossible to reach by standard methods.
- Careful design and construction, especially regarding thermal drifts, keep the mid and long term stability also in the arc-second range.
- Using free surfaces of liquid as both a flat and an horizontal reference avoids the need for a huge flat of good optical quality, and allows to define verticality of a mount axis accurately, even when the movements of the mount are limited and prevent the use of half-turns.
- Such a tool proves to be very valuable in lightening the alignment chores of a Laser Ranging station.