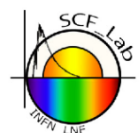
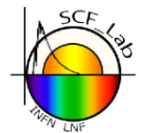
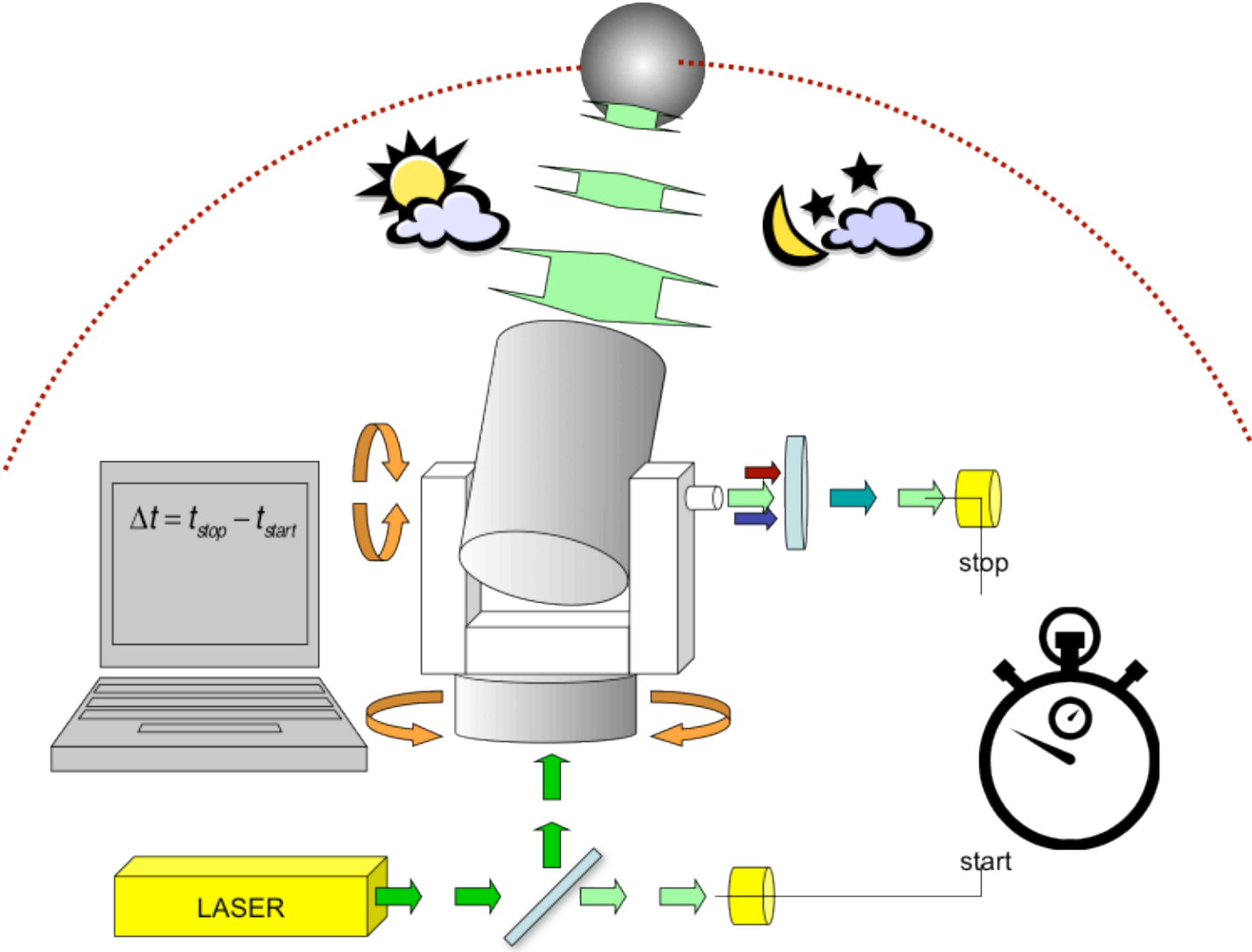


Optics and the SCF_Lab: A very brief introduction

EDIT 2015 - INFN-LNF

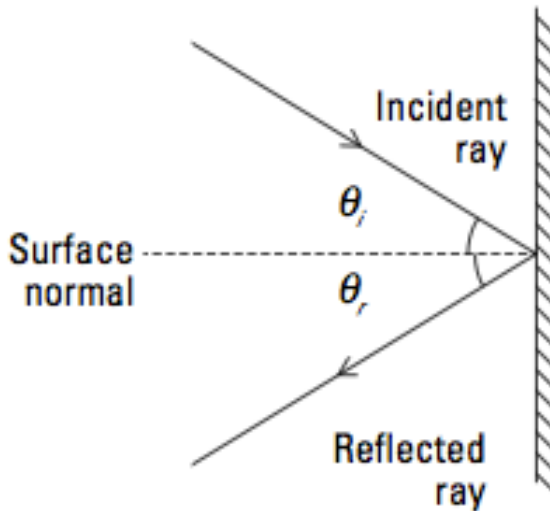


Optics and ranging techniques



Specular reflection

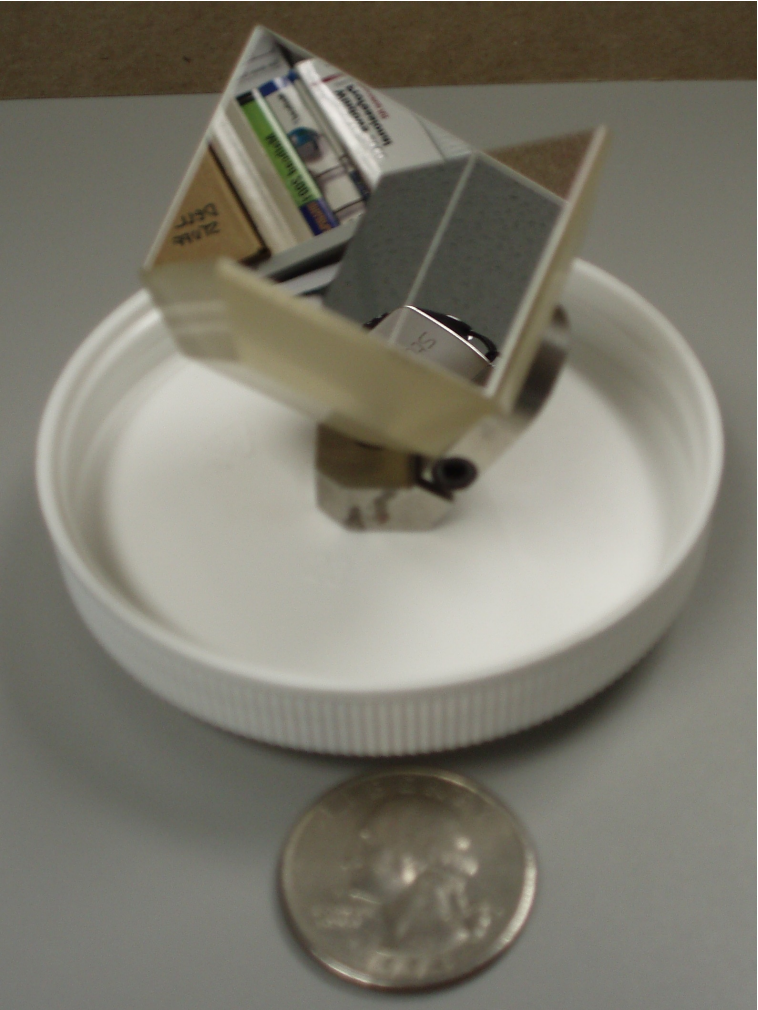
If you look at a single ray *incident* on a surface (traveling toward and hitting a surface), you need to be able to determine the ray's orientation relative to the surface so that you can calculate the new path that the light will take after bouncing off the surface.



With the convention for measuring the orientation of the light rays relative to a surface established, the law of reflection is

$$\vartheta_i = \vartheta_r$$

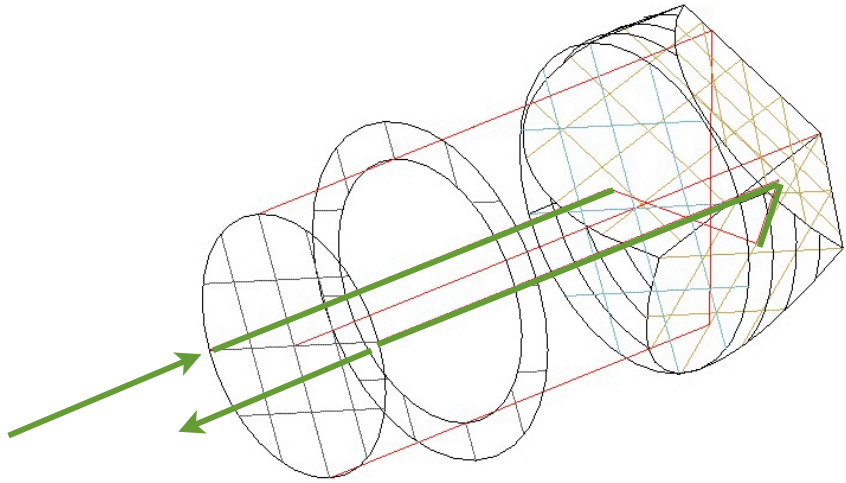
Optics and ranging techniques



Optics and ranging techniques

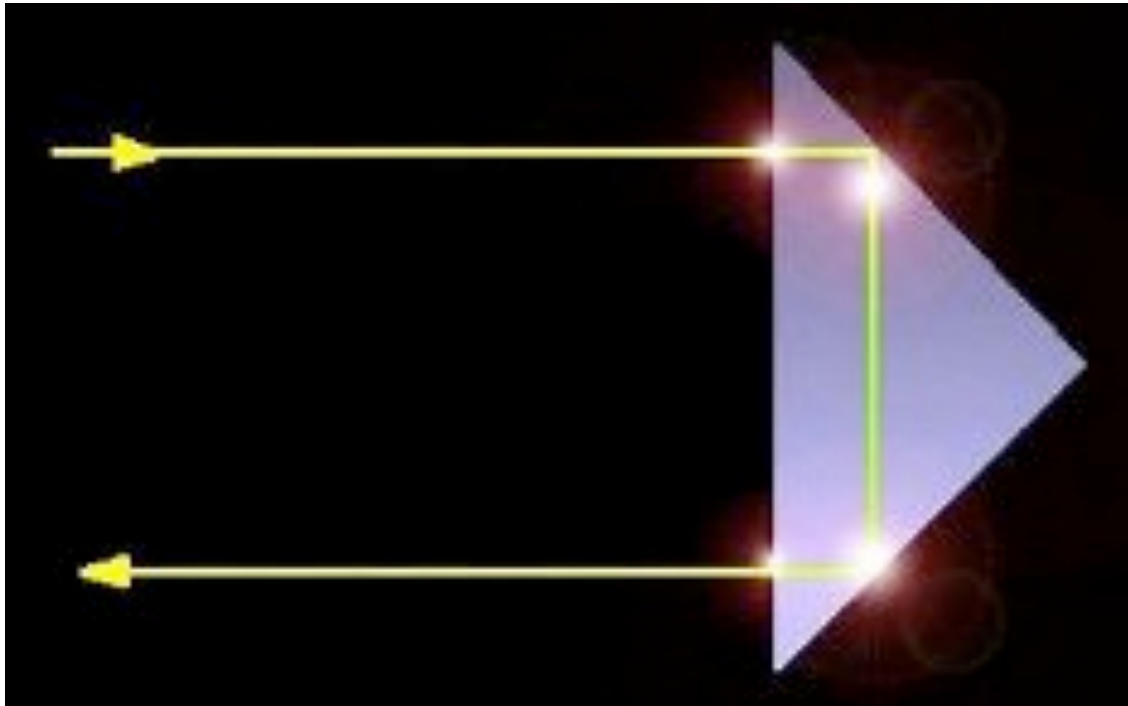


- A CCR is a prism, usually made of fused silica, whose vertex is the corner of a cube.
- Every CCR back face has an angle of 90° with the two remaining faces.
- A ray entering the CCR is retroreflected along the very same incidence path.
- A ray entering the CCR comes out in a point opposite to the origin.



reflection on the three back surfaces through total internal reflection

Total internal reflection

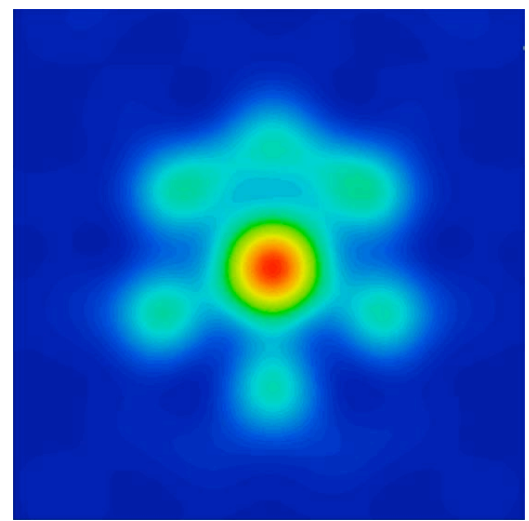
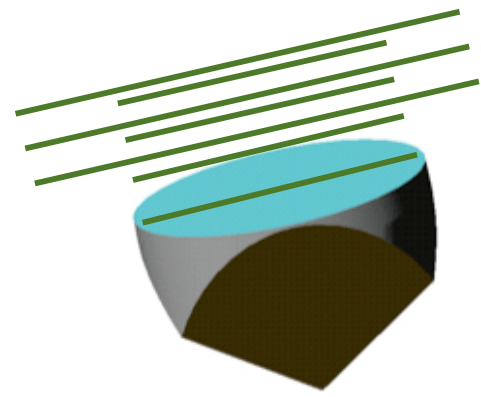
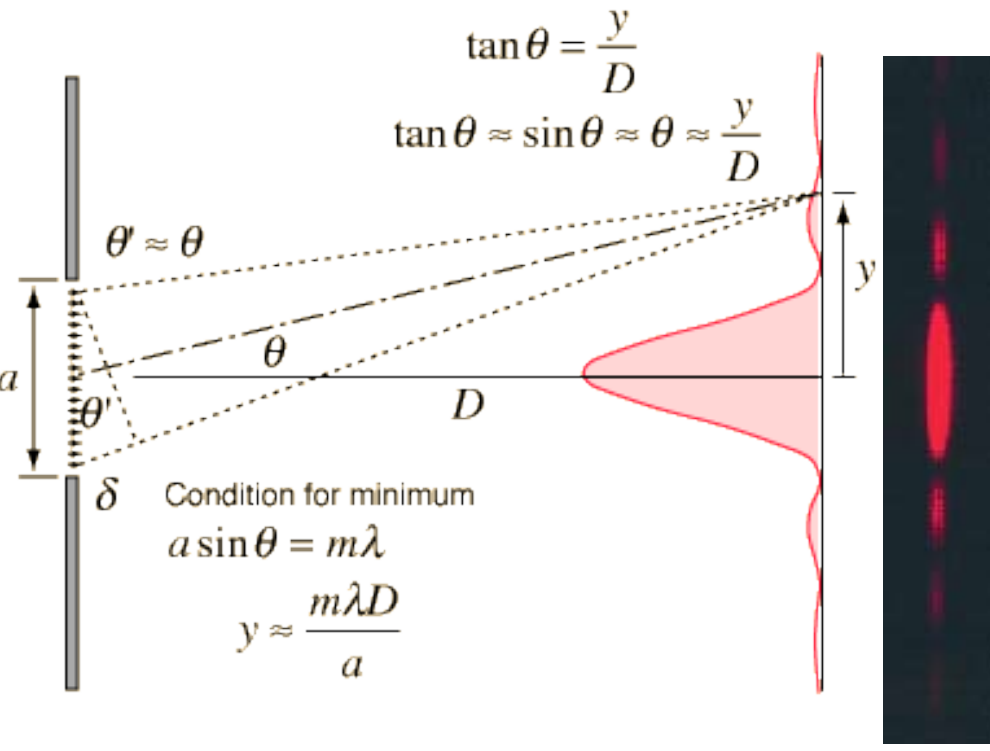


TIR due to the fact that incidence angle between light beam and CCR back face is greater than glass/air critic angle (which is about 45°). It is the same principle used in optical fibers.

When there is not TIR, then part of the energy carried by light may get through CCR back faces, originating thermal disturbances.

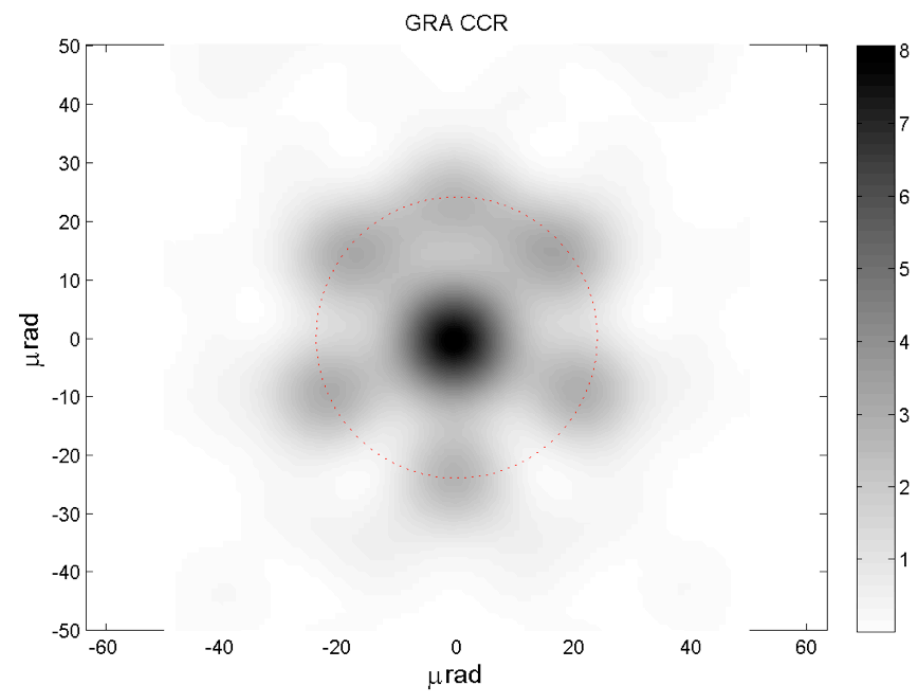
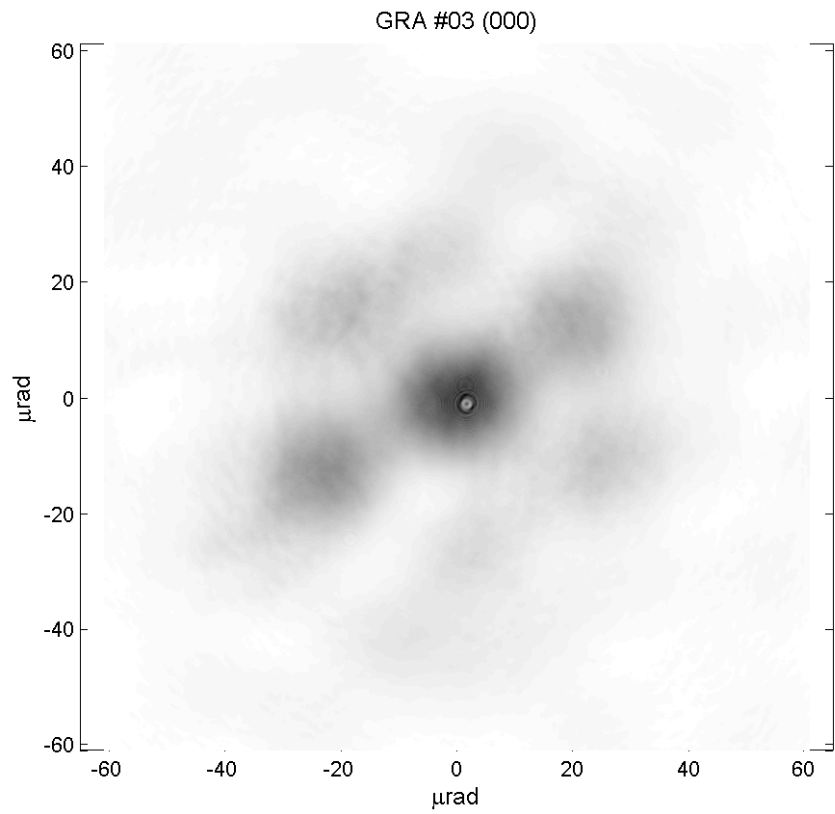
Far field diffraction pattern

Diffraction is a phenomenon that occurs when a wave passes by an obstacle or thru an aperture. On a distant screen the resulting wave will have a known intensity variation, which takes with it fingerprints of the interacting obstacle/aperture.



Optical sims realized by ORA's Code V

Far field diffraction pattern



Fraunhofer distance:

$$d_f \approx D^2 / \lambda$$

where, in our case, as an example:

$$D = 5 \text{ cm}, D^2 = 25 \text{ cm}^2 = 25 \times 10^{-4} \text{ m}^2,$$

$$\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m} = 5 \times 10^{-7} \text{ m},$$

and, therefore, as an estimate:

$$d_f \approx 25 \times 10^{-4} \text{ m}^2 / 5 \times 10^{-7} \text{ m} = 5 \times 10^3 \text{ m} = 5 \text{ km}$$

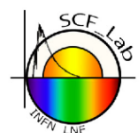
That is to say that far field limit has to operate on very long baselines!

Near vs. far field limits

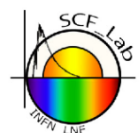
As you can see our optical bench is not that wide...
What is going on?

Using optical grade component, we stretch and expand the optical path as if it were much longer than it actually is... In fact we simulate lunar laser ranging amongst the other!

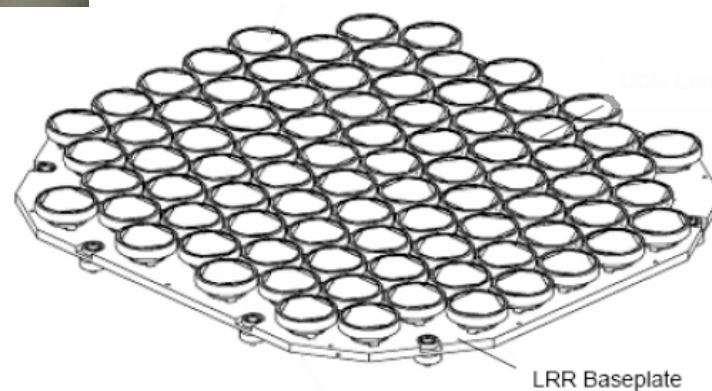
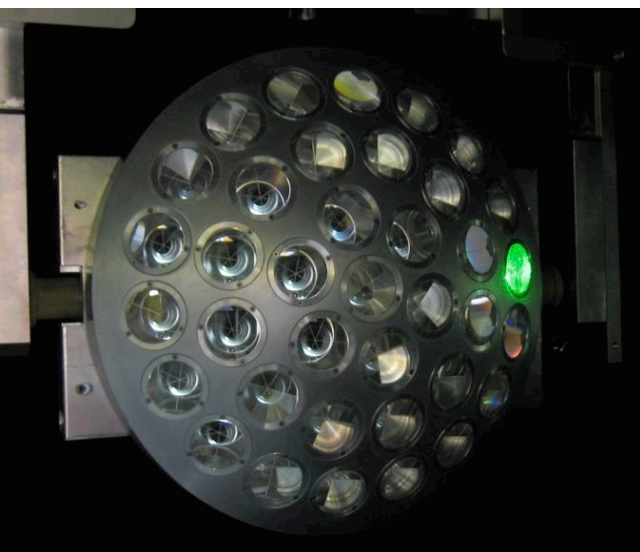
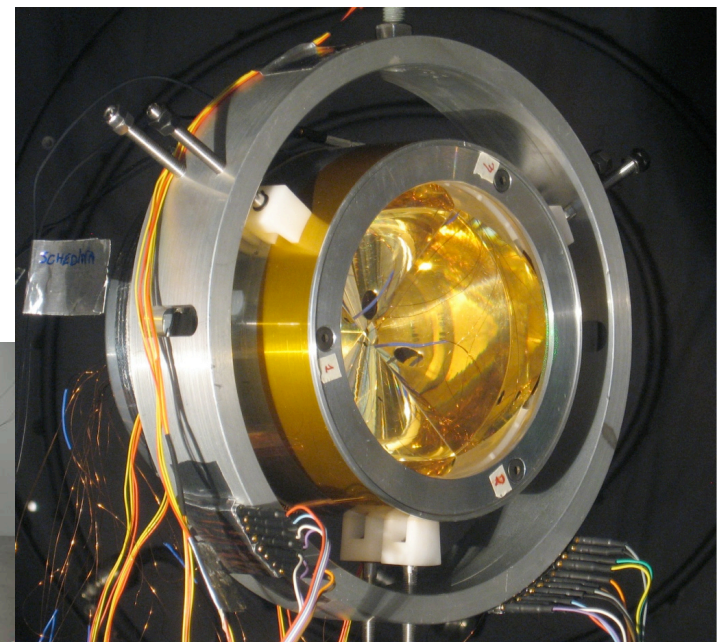
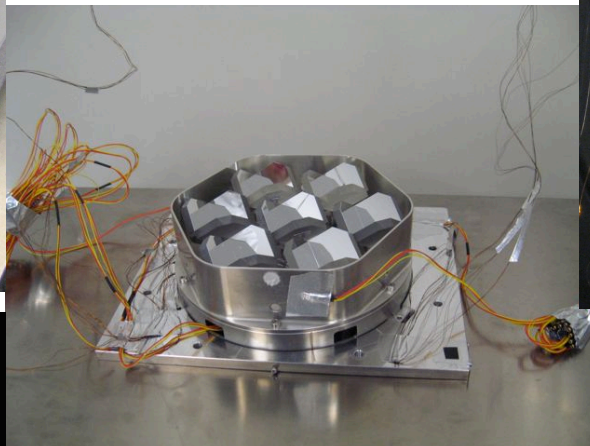
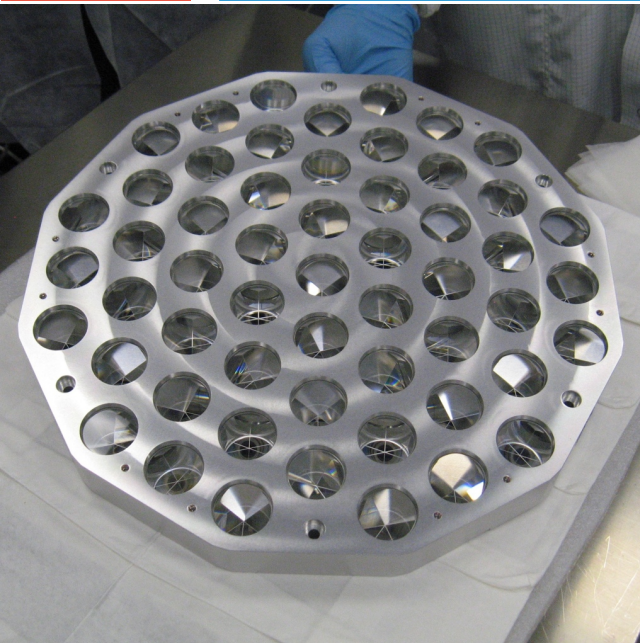
We will then introduce some techniques in order to see whether our far field approximation is working or not.



- Collaboration with NASA to characterize **LAGEOS** satellite CCRs.
- Characterization of a **Galileo-IOV retroreflector** for ESA.
- **ETRUSCO-2** project for design and characterization of a retroreflector payload for the GNSS (GRA).
- Design and characterization of a retroreflector payload for the **next generation Lunar Laser Ranging**, in collaboration with University of Maryland.
- SCF_Lab measurements of current GNSS retroreflector payloads (**IRNSS** and **Galileo**).
- Design of payloads for next generation **Earth observation satellites** with Italian Ministry of Defense.
- Design of payloads for **laser altimetry** on solar system planets and moons (Mars and Moon).



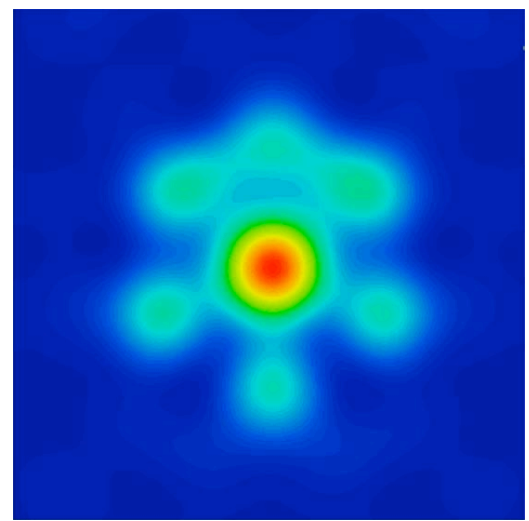
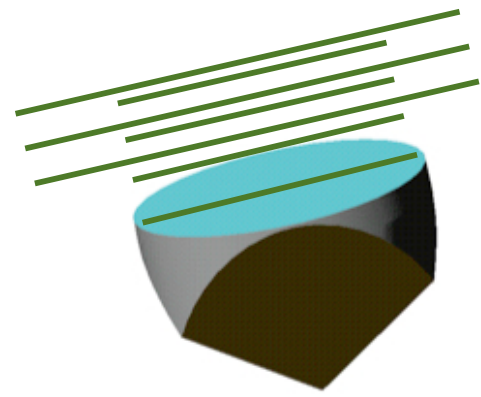
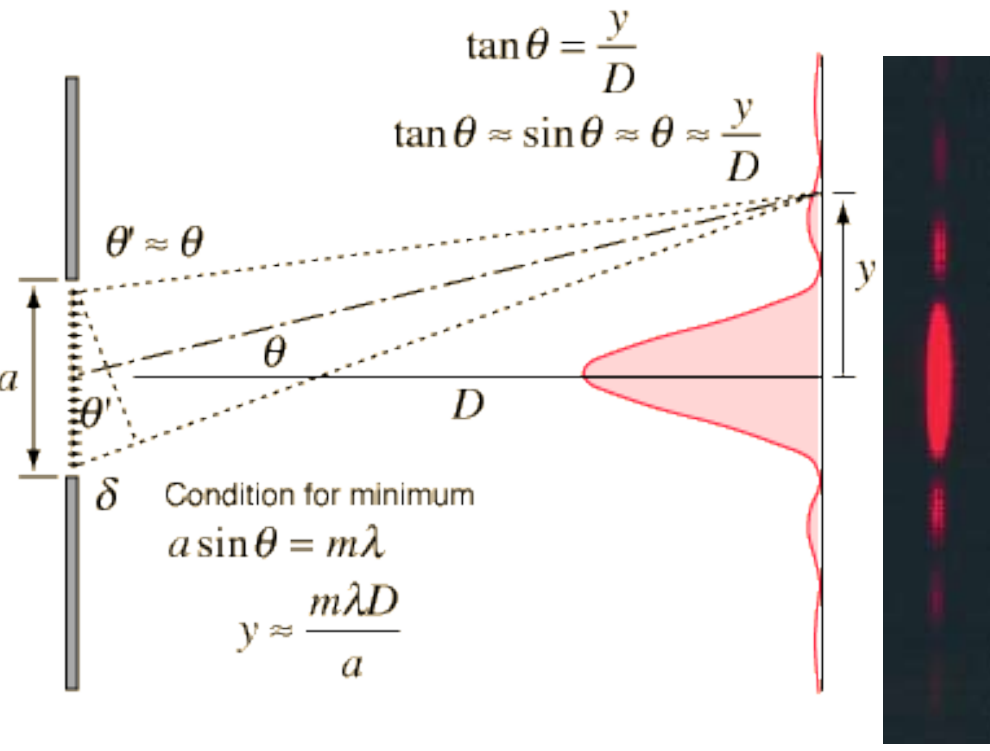
SCF_Lab laser retroreflectors



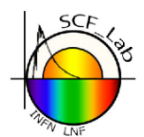
LRR Baseplate

Far field diffraction pattern

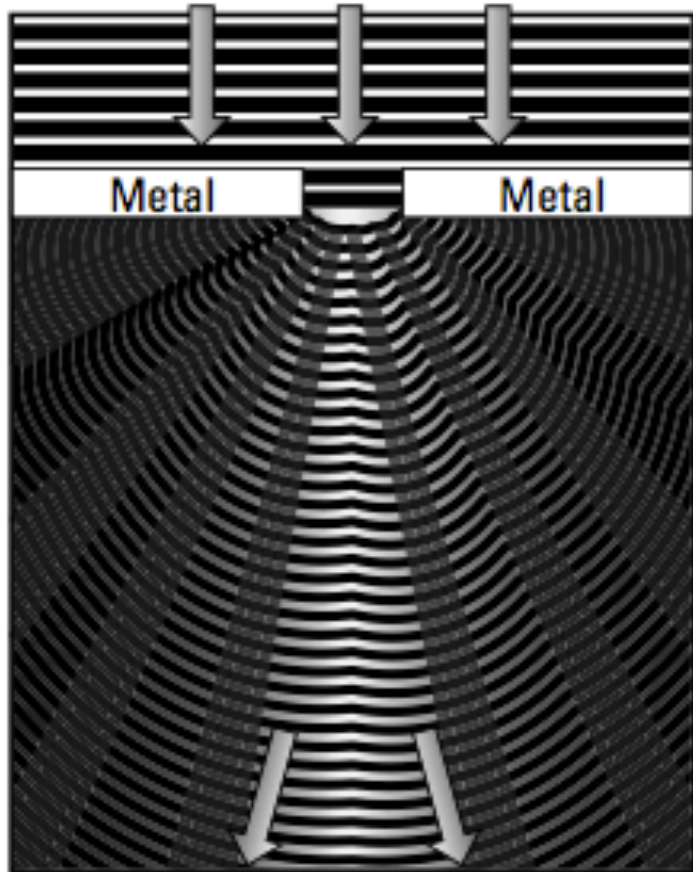
Diffraction is a phenomenon that occurs when a wave passes by an obstacle or thru an aperture. On a distant screen the resulting wave will have a known intensity variation, which takes with it fingerprints of the interacting obstacle/aperture.



Optical sims realized by ORA's Code V



Again on diffraction



Diffraction is a phenomenon that happens around you all the time; you're just not able to perceive it. *Diffraction* occurs when light encounters an obstacle, such as an edge of a piece of paper or a piece of metal with a hole in it, and expands to try to fill the area behind the obstacle.

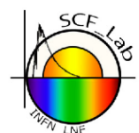
Even though diffraction and refraction both deal with the bending of light, **they don't describe the same phenomenon**. Refraction requires a change in index of refraction. Diffraction doesn't depend on the index of refraction and happens only when an opaque obstacle is present in the path of the light.

Interference

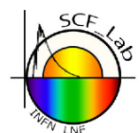
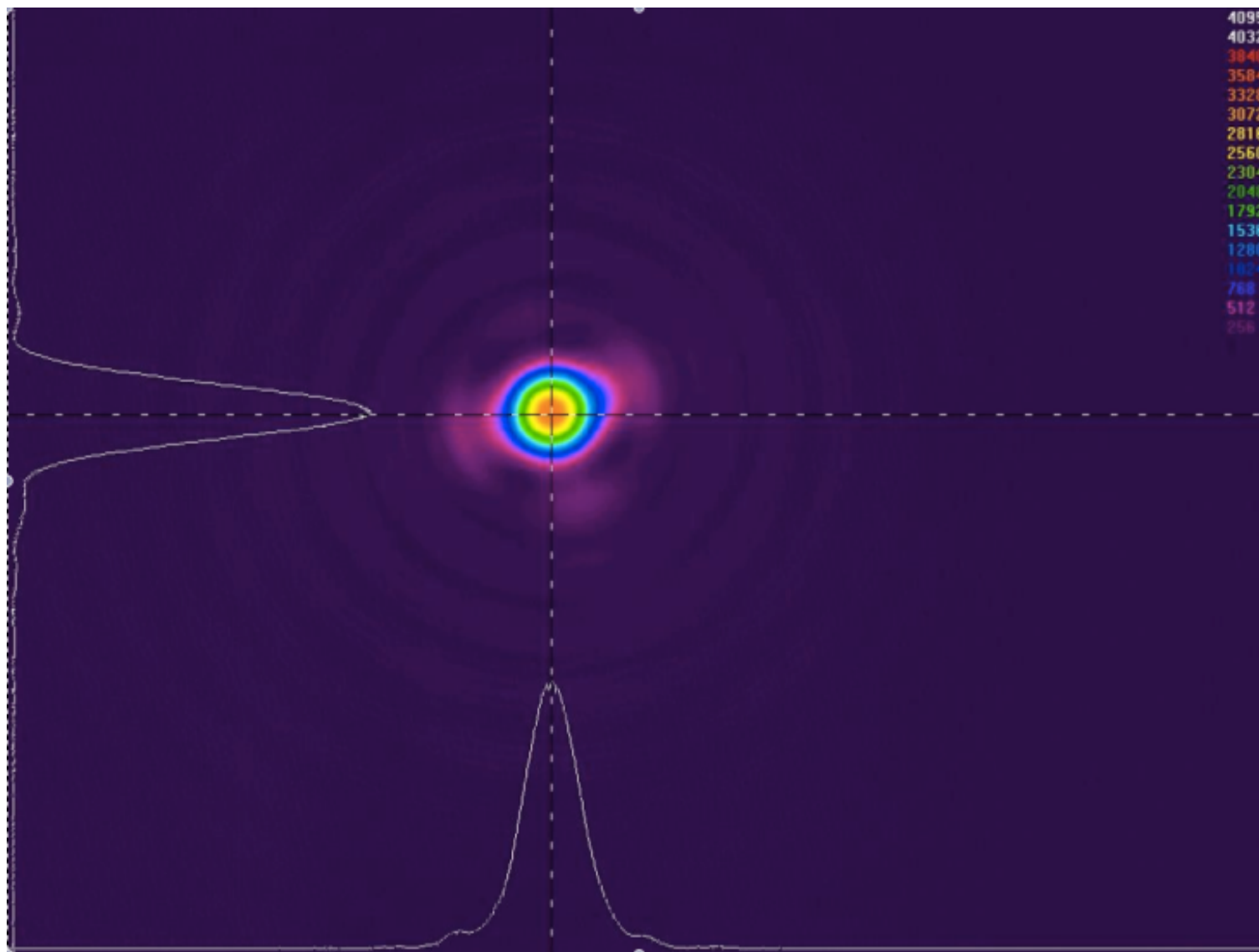
Interference of light rays from the same source causes diffraction patterns; light from different sources causes interference patterns. You can tell which phenomenon is responsible for the light and dark pattern you see based on the spacing between the light and dark areas, or fringes.

Interference causes equally spaced fringes; diffraction causes fringes that aren't equally spaced.

We will see this phenomenon in details later (the Young experiment).



FFDP optical circuit cals - 1



Optical bench:

INTENSITY CALIBRATION OF OPTICAL BENCH WITH THE AIRY PEAK METHOD

In order to verify that the optical bench works properly, one has to use a flat mirror, whose Far Field Diffraction Pattern (FFDP) is usually known as Airy Peak.

First thing, one has to verify that the FFDP shape corresponds to an Airy Peak one, known from optics literature; then, one has to verify that the distance between the central peak and the first trough is

$$\theta = 1.22 * \lambda / D,$$

where,

θ = angular distance between central peak and first trough

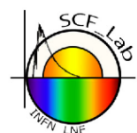
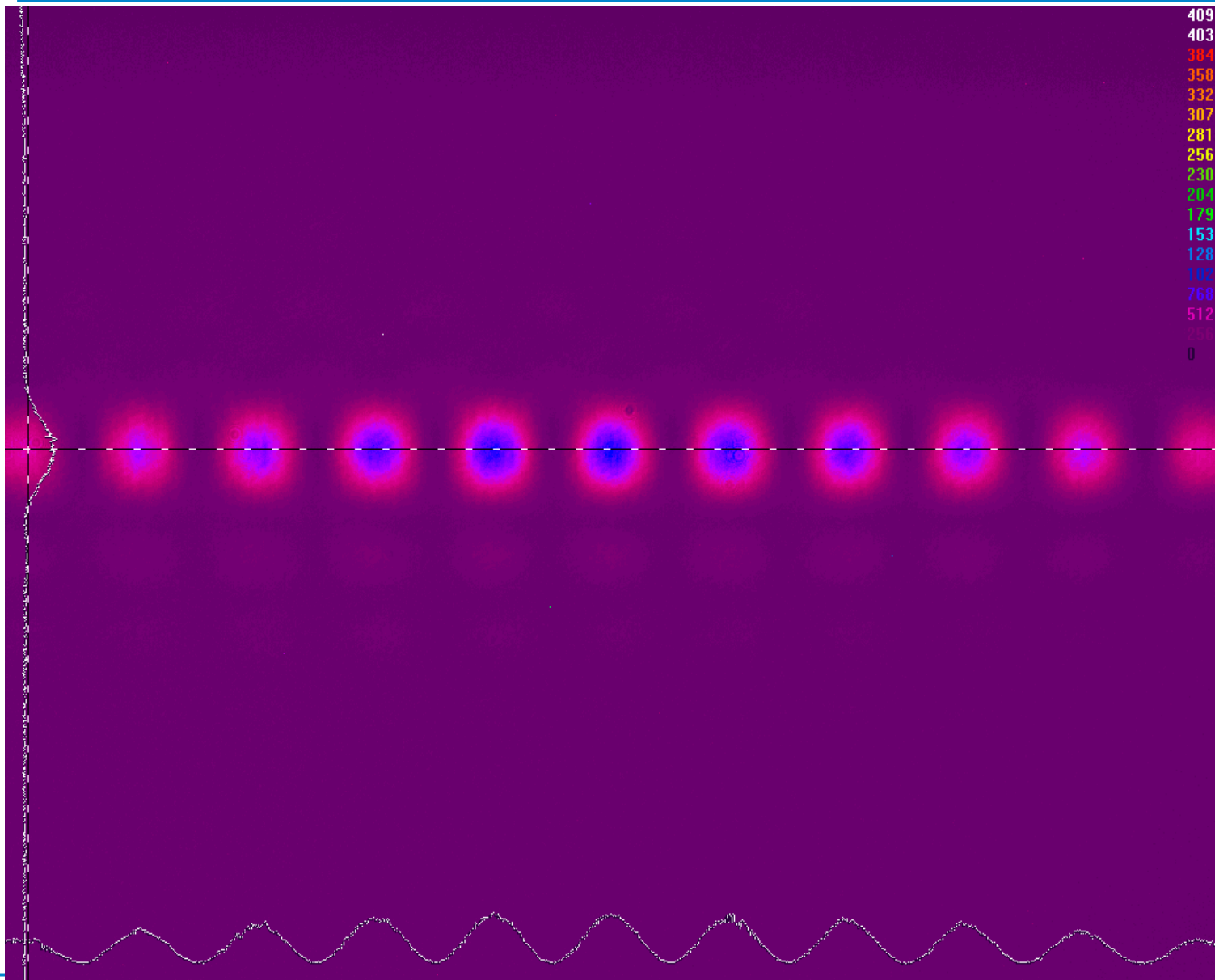
D = flat mirror diameter

λ = laser wavelength.

In our case, $\theta \approx \lambda / D = 500 \text{ nm} / 5 \text{ cm} = 500 \times 10^{-9} \text{ m} / 5 \times 10^{-2} \text{ m} = 10^{-7} / 10^{-2} = 10^{-5} \text{ rad} = \text{few } \mu\text{rad}$.

This value has to be in accordance with the quantity measured via CCD software.

FFDP optical circuit cals - 2



Optical bench:

ANGULAR CALIBRATION OF OPTICAL BENCH WITH THE DOUBLE SLIT METHOD

According to Young experiment, a double slit is placed at the exit of the beam expander and before a flat mirror. The resulting pattern is characterized by a sequence of peaks and troughs, whose angular separation is given by

$$\theta = \lambda / d,$$

where,

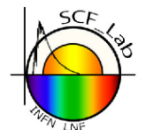
θ = angular distance between two peaks

d = linear distance between slits

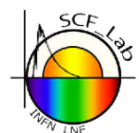
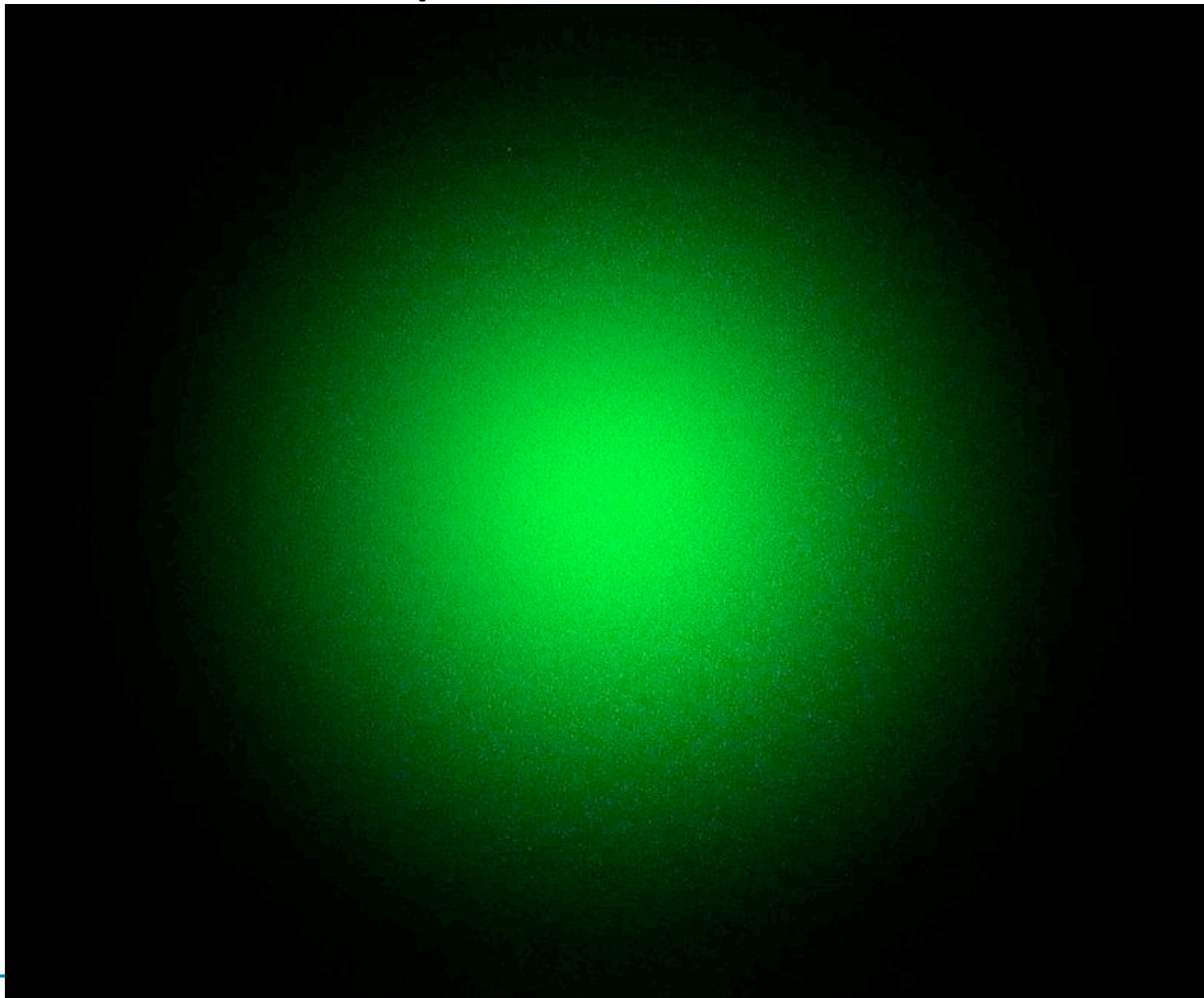
λ = laser wavelength.

In our case, $\theta \approx \lambda / d = 500 \text{ nm} / 1 \text{ cm} = 500 \times 10^{-9} \text{ m} / 10^{-2} \text{ m} = 5 \times 10^{-7} / 10^{-2} = 5 \times 10^{-5} \text{ rad} = \text{few } \mu\text{rad}$.

Distance between two peaks is measured through CCD camera proprietary software, and the computed value of θ is used to pass from micrometers to microradians.



FFDP optical circuit cals - 3



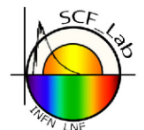
Optical bench:

BEAM INTENSITY DISTRIBUTION

Gaussian beam is a beam of light whose intensity distributions are well approximated by Gaussian functions.

We measure the intensity drop to $1/e$ or $1/e^2$ of the axial value and this information is used to model the actual shape of the intensity distribution.

<http://www.newport.com/Gaussian-Beam-Optics/144899/1033/content.aspx>



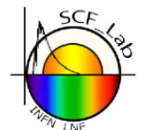
If you want to know everything about laser ranging, please have a look at:

<http://ilrs.gsfc.nasa.gov>

<http://ilrs.gsfc.nasa.gov/about/reports/index.html>

<http://ilrs.gsfc.nasa.gov/about/reports/biblio/index.html>

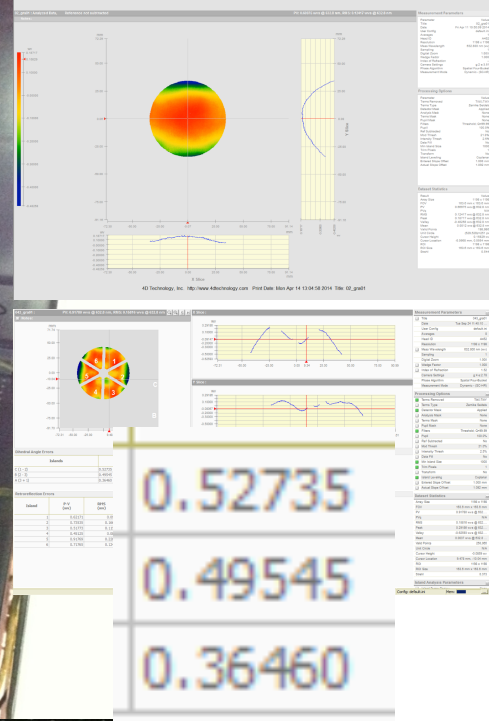
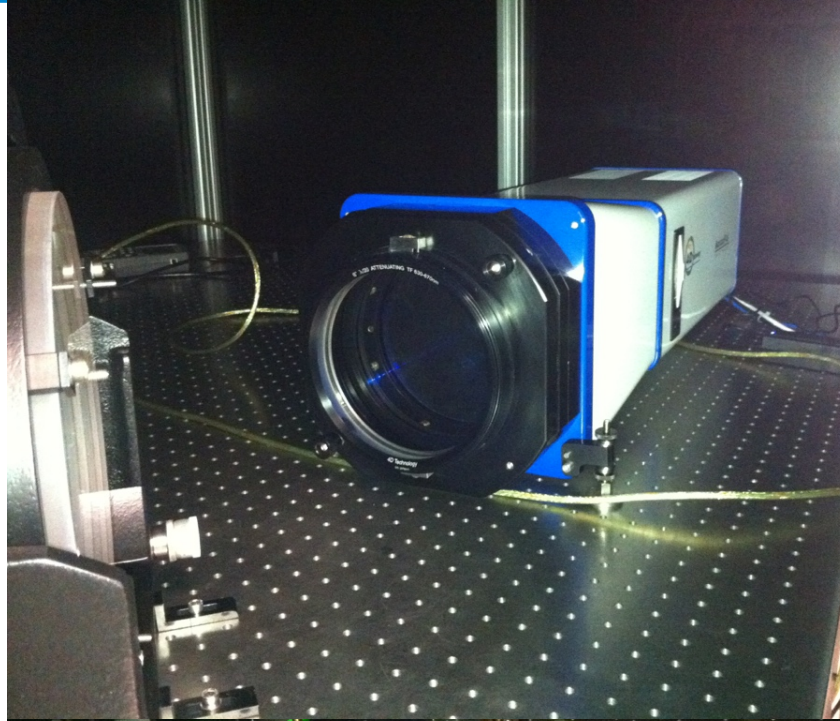
<http://www.Inf.infn.it/esperimenti/etrusco>

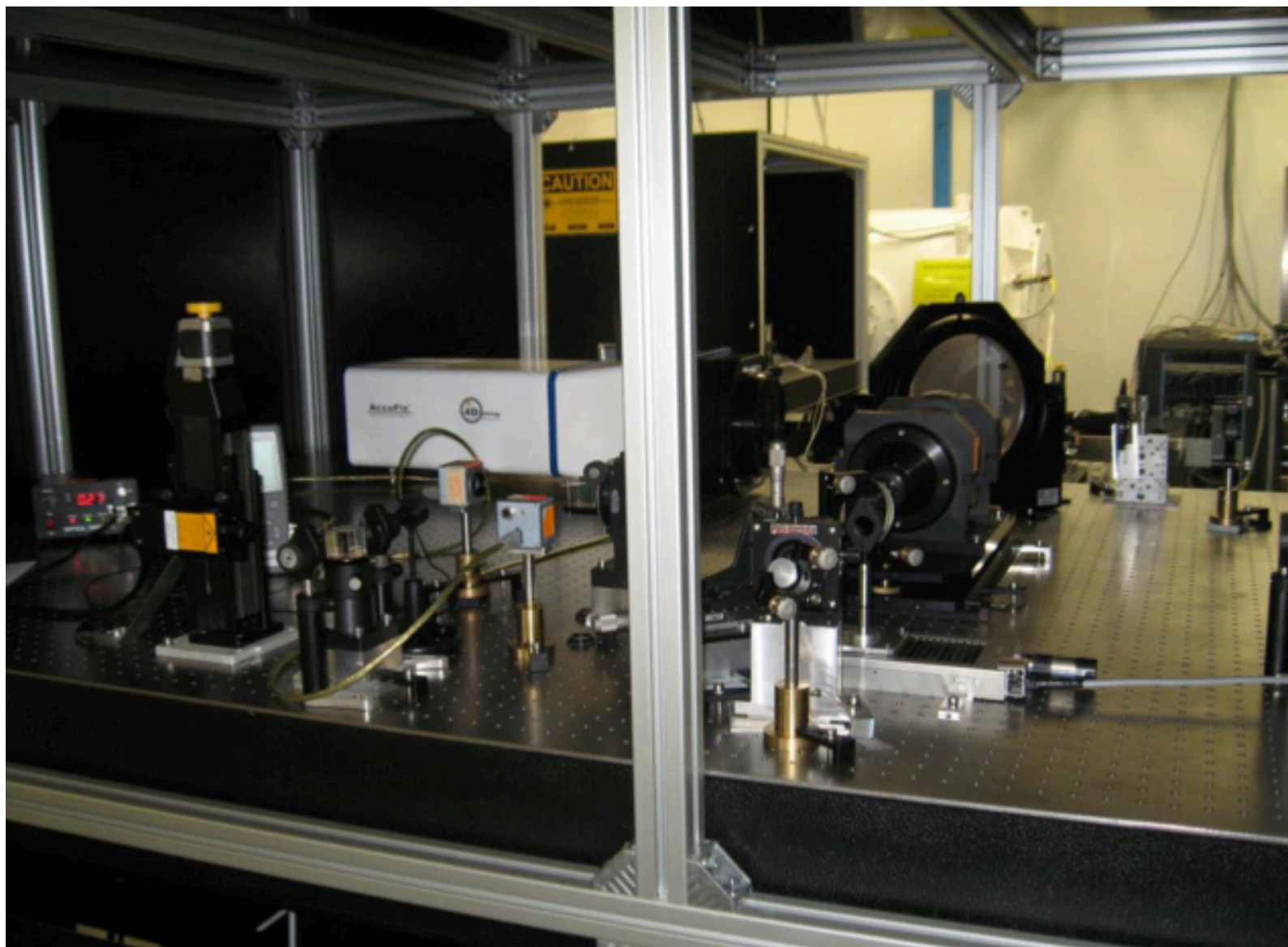


Interferometry @ SCF_Lab

Fizeau laser interferometer for high accuracy shape and transmitted wavefront measurements (e.g., flatness testing, shape measurement, thickness uniformity, ...)

Thanks to 'Premiale' MIUR (Laser Ranging to Galileo) we shall get a 45-cm beam expander to comprehensively test whole payloads!





Safety measures

Do not directly observe the laser beam.

When the black protective case is opened to access the optical circuit, use the protective goggles.

Always close the protective cover during measurements.

Prevent the optical circuit to be at the level of the eyes and in general avoid direct or accidental eyes exposure.

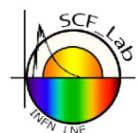
Take particular care when operating with reflecting surfaces in order to avoid undesired reflections.

Put beam dumping devices where the beam deviates from the optical circuit.

Use specific precautions if working with non visible laser beams $\lambda < 400$ nm and $\lambda > 700$ nm.

Do not use observation optics to directly observe the beam.

Do not expose the skin directly to the beam.



Thanks!

