ELECTRON AND LASER BEAMS MUTUAL ALIGNMENT IN SPARC-LAB (INFN)

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Abstract

In the SPARC accelerator the electron beam and the laser beam crosses at an interaction point of really small size. So both the beams has to be precisely and mutually aligned. As for the laser, scientists use to make manual alignment by means of mirrors and irises, using a low power pointing laser. This is definitely unpractical in the accelerator environment, where the access is forbidden during the operation: so the laser beam has to be aligned precisely with respect to the nominal path before turning on the electron beam. A special support for the pointing laser has been designed and fabricated. The support has four mounting holes for the laser tracker CCR, so it can be aligned with respect to the nominal beam line. In the paper the procedure for the pointing laser characterization, the alignment work, as well as the evaluation of the accuracy obtained, are reported.

MECHANICAL SUPPORTS

The assembly of the pointing laser with its support (assembly A) has to be calibrated to find the relashionship between the position of the four CCR put on the support and the laser beam line. Actually, even if the support is precisely fabricated, the exit direction of the pointing laser isn't exactly concentric to its cilyndrical case (max deviation 5 mrad) and therefore it isn't related to the four CCR. So we need a referenced target to receive the beam and establish precisely his direction. We decided to make a plate with four holes for CCR nest (assembly B), similar to the first one, carrying a hole to receive the laser spot.

Both supports have been fabricated in our workshop using a CNC machine.

The mechanical supports have been measured by a CMM to establish the geometric relation between the four CCR and the laser output (on assembly A) and the four CCR and the target hole for the laser spot (on assembly B). Figure 1.

SETUP & CHARATERIZATION

The pointing laser used is a Thorlabs CPS532-C2, a collimated and compact diode laser with the following specs in Table 1.

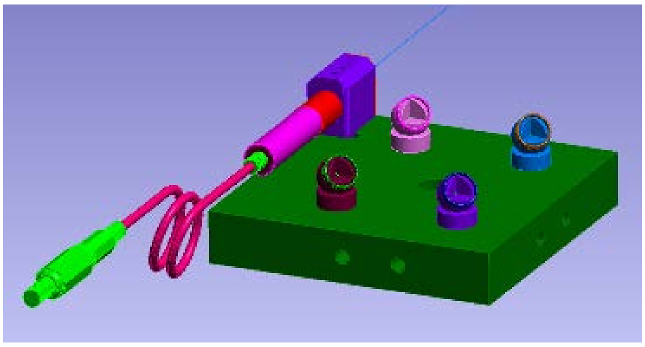
The laser beam starts with a 3,5mm round spot size, but, due to the beam divergence of 0.5 mrad, the spot is 6 mm after 5 m and 8.5 after 10 m.

Table 1: Laser beam specifications

General Specifications	
Housing Material	Aluminum
Housing Dimensions	Ø11.0 mm x 72.8 mm
Beam Shape	Round, Ø3.5 mm
Operating Temperature	10 to 40 °C
Storage Temperature	-30 to 70 °C
Operating Voltage	4.9 V to 5.2 V
Laser Safety Class	2

Optical and Electrical Specifications	Min	Typical	Max
Wavelength	531 nm	532 nm	533 nm
Power	0.8 mW	0.9 mW	1.0 mW
Polarization Extinction Ratio	-	5 dB	-
Power Stability (8 hours)	-	-	5%
Power Stability (1 Minute)	-	-	2%
Axis Deviation	-	-	5 mrad
Beam Divergence	-	-	0.5 mrad
Operating Current	-	120 mA	200 mA

In our lab, we setup the distance (max available) around 3,5m obtaining a spot size on target around 5,2mm.



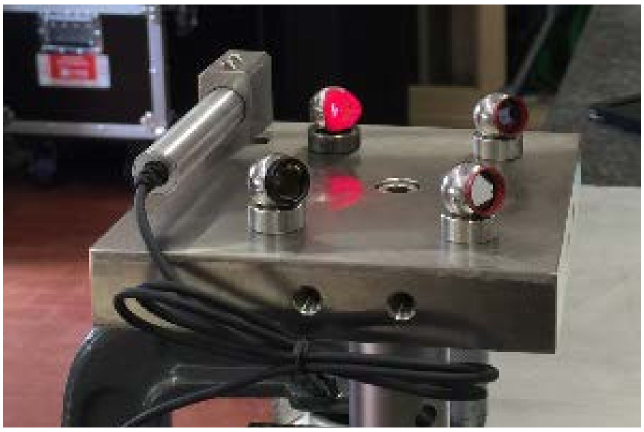


Figure 1: Assembly A

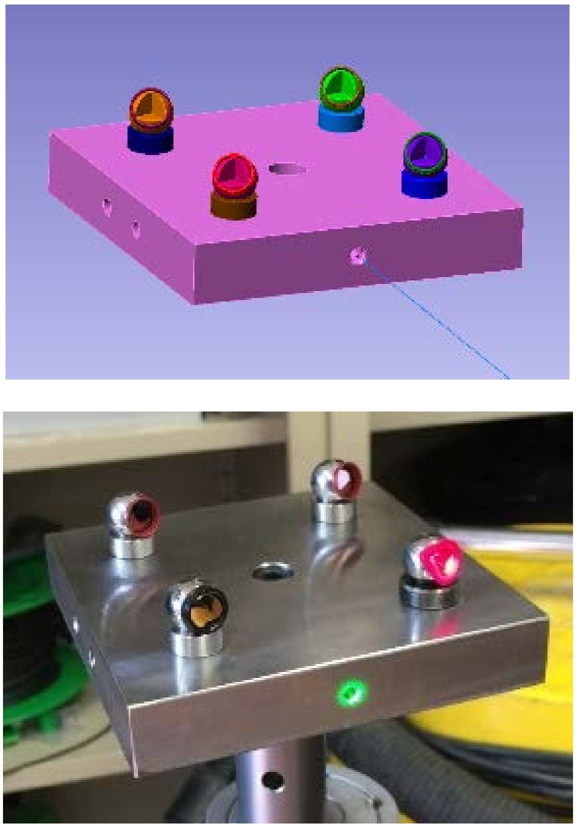


Figure 2: Assembly B.

Then we set the two assembly on stands with micrometric stages, then adjusted their position by the micrometric screws until the pointer beam hit the target hole. The axis deviation is not a problem because the target is centered manually.

Finally, we measured by Laser Tracker the positions of the CCRs of both the pointing laser and the target.

At this time we were able to know the beam direction with respect to the CCRs of the assembly A and therefore to point precisely the beam line wherever we need.

We know where is the laser line in every position in which we move the support, **even if we don't see it!**

Obviously, characterization is valid still the laser case remains fixed to the support.

This is a very powerful tool because let us align any mechanical assembly or any single part inside the vacuum chambers of the accelerators. Just set the pointer assembly in front of a suitable inlet window, position it by the laser tracker along the right path so to spot the target. The target, usually visible by a video camera, is then adjusted by its remote handling.

APPLICATION IN SPARC-LAB

A work in the Thomson beam-line in Sparc-Lab has been the first opportunity to test this alignment tool kit. The task was to check both the alignment of a 45° motorized mirror used for beam diagnostic and the position center of a parabolic holed gimbal mirror. The electron beam normally passes through the hole of the parabolic mirror, while the 45° mirror can be inserted in the vacuum chamber for deviate the beam to a diagnostic equipment or extracted to let the beam pass.

The pointer assembly was approximately positioned on a column in front of a window, coaxial with the beam line, on a branch of a dipole vacuum chamber in the starting part of the Thomson beam line. The Laser Tracker was mounted in a suitable position to reach all the CCR on laser and target assemblies.

For a faster job, a CAD file with all the CCR of the pointer and of the target assemblies, as well as the main elements of the Thomson beam line coaxial with the laser pointer line was prepared and loaded in the SA alignment software.

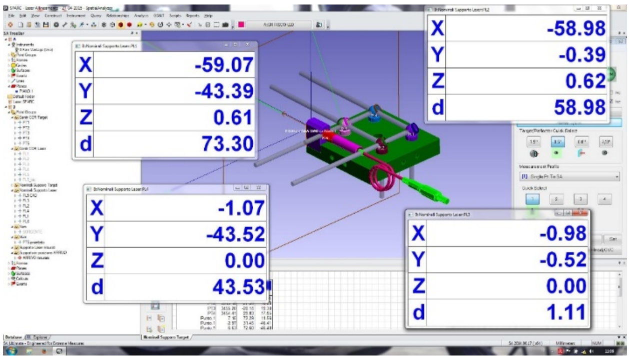


Figure 3: Spatial Analyzer SW.

First, all visible Sparc-Lab reference network points were measured to locate, with a best fit, the laser tracker, and match the CAD model with the real line.

Applying micrometric movements to Y, Z, Pitch, and Yaw on laser assembly (X and Roll not needed), the pointer laser line was moved on the nominal beam line. All movements can be done watching the live window "watch to point" in SA for all the four CCR on the pointer assembly.

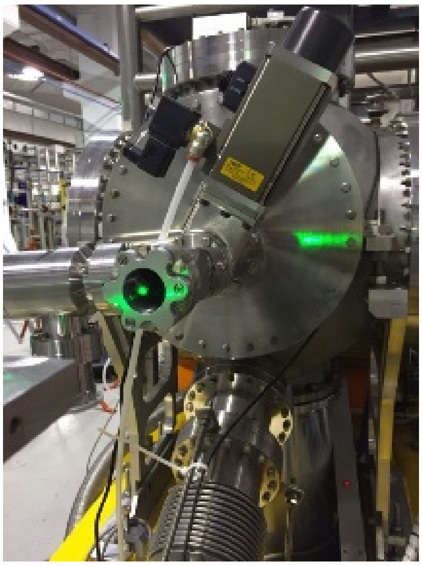


Figure 4: Laser spot on diagnostic window.

In this case we verified the alignment watching the pointer spot on the target at the end of the vacuum chamber with the 45° mirror off line, through a glass window. A YZ stage was sufficient to put the target in position, after being put approximately perpendicular to the beam. The green spot on the target is visible in the above picture, while below the spot is visible on the glass window after the insertion of the 45° mirror. Figure 3.

TECHNICAL ANALYSIS AND R&D

ADVANTAGES

- This technique may be useful to align diagnostic assembly or similar parts without an iterative and time consuming alignment process with accelerator on/off.
- It is possible align optical elements having only one input access point on the line of interest.
- There is a significant saving of precious MachineTime to dedicate to experimental operations.
- Custom economical solution may be installed on different Machine line to be referenced and used to verify optical transportation in every moment.

DISADVANTAGES (to work on)

- Target may be simplified in same application using an only mechanical support to use with a target tape and a CCR offering the same center point.
- There is a limit concerning this diode laser spot size. It is good on short distance (5-10 m). Farther, the laser spot is useless, too big with a center that becomes unrecognizable.
- When this technic is used without the check with the final target, the uncertainty due to the of laser tracker alignment and to the sensibility of the mechanical micrometric regulation has to be considered.