Design of collimated laser beam optics for the KEKB injector linac alignment system

THP076

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Introduction

A new laser-based alignment system is under development in order to precisely align accelerator components along an ideal straight line at the KEKB injector linac. The new alignment system is strongly required in order to stably accelerate high-brightness electron and positron beams with high bunch charges and also to keep the beam stability with higher quality towards the next generation of B-factories.

The new laser-based alignment system consists of the LD mounted on auto stage, vacuum duct, photo diode (PD) and PD detector. To eliminate the laser beam size dependent response of PD, the collimated laser beam propagation along the linac (around 500-m-long) is strongly required. In this paper, we will report the design of collimated laser beam optics for the KEKB injector linac alignment system in detail.

KEKB Injector Linac

- 600-m-long electron/positron injector:
  - 100-m-long straight section
  - 500-m long straight section
- Provides the beams for four independent rings:
  - KEKB e-: 8 GeV, 1 nC
  - KEKB e+: 3.5 GeV, 1 nC (primary electron : 3.7 GeV, 10 nC)
  - PF: 2.5 GeV, 0.1 nC
  - PF-AR: 3 GeV, 0.2 nC

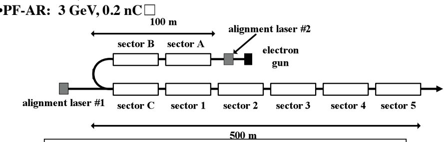


Fig. 1: Schematic drawing of KEKB Injector Linac

Laser alignment system

(1) Laser Diode (Mitsubishi Electric, ML101J27)
- Single mode fiber coupling (core diameter: Φ3.5 μm)
- Wavelength : 660 nm (red)

(2) Laser direction control: 5-axis autostage
- X, Y, Z, θ , and ϕ

(3) Quadrant silicon photodiode (PD)
- Φ10 mm (OSI Optoelectronics, Model SPOT-9D)

(4) Detector

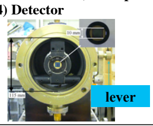


Fig. 2: Photograph of PD and chamber

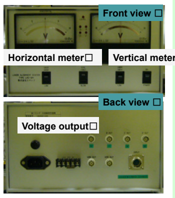


Fig. 3: Photograph of detector module

Alignment method

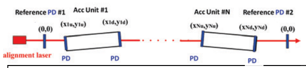


Fig. 4: Schematic drawing of laser-based alignment

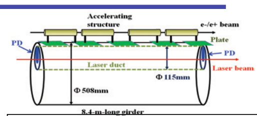


Fig. 5: Girder and accelerating structure

(1) Reference laser line:
At the most upstream/downstream position (PD#1, PD#2) , adjust the laser position and angle like ($X_{\#1}$,$Y_{\#1}$) = ($X_{\#2}$,$Y_{\#2}$) = (0, 0)

(2) Alignment measurement and adjustment
•At Acc. Girder #N, adjust the girder position so that PD position is (XNu, YNu) = (XNd, YNd) = (0, 0).
(*) Pre-alignment has been carried out before girder installation. Relative position among center of PD, accelerating structure, and plate

Optical system

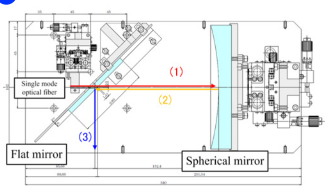


Fig. 6: Schematic drawing of optical system

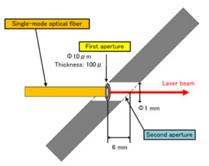


Fig. 7: Enlarged drawing of flat mirror

- Optical system consists of a flat mirror and spherical mirror (D=152.4, f = 152.4 mm)
- Fiber scheme:
  - Reduction of pointing stability
  - Power supply of laser can be installed in klystron galley (avoidance of radiation injuries)
- First aperture makes the diffraction beam. Second aperture cut the side-lobe. Only narrow main-lobe beam is utilized for the alignment measurement (Airy beam)

Results (waisted beam)

Simulation

GLAD Ver. 5.5

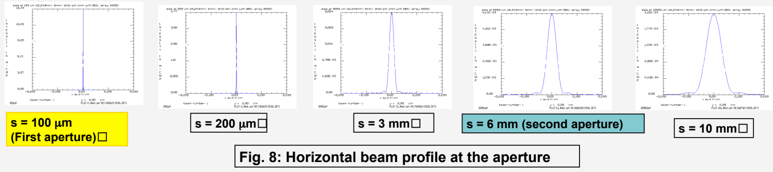


Fig. 8: Horizontal beam profile at the aperture

Measurement

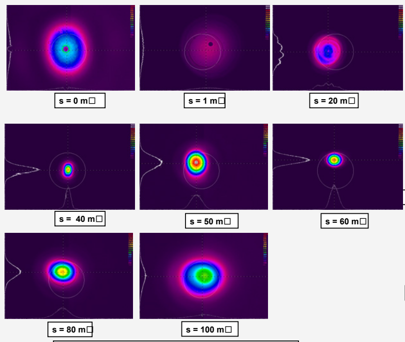


Fig. 9: Laser profile (atmospheric)

Simulation

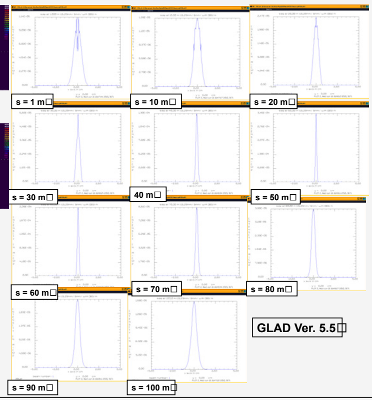


Fig. 10: Horizontal profile
Waist position: 50m
Distance between fiber and spherical mirror: 15.29 mm

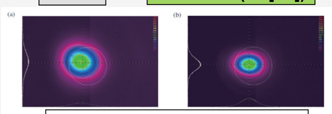
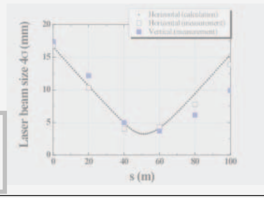


Fig. 11: Laser profile at 100-m point

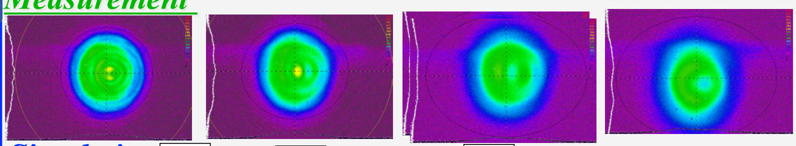


·Difference between horizontal and vertical waist position is caused by the oblique incidence to spherical mirror.

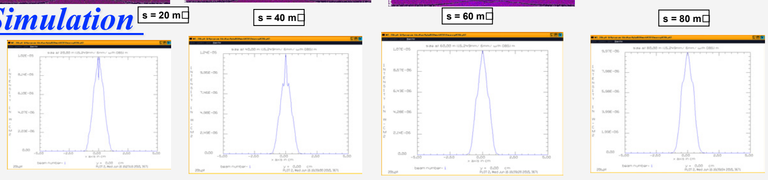
Fig. 12: Simulation and measurement result of laser beam size

Results (collimated beam)

Measurement



Simulation



Summary and *Future Plan*

- Laser-based alignment system by using PD with Φ10 mm
  - Need a collimated beam propagation along 500-m-long as small diameter as possible.
- Reconstruction of alignment system in KEKB linac:
  - Development of the new optical system and laser source.
  - Preliminary test at 100-m-straight line and simulation have been carried out.
- Results of measured and simulated beam sizes.
  - Good agreement for waisted beam
  - Bad agreement for collimated beam
- More accurate simulation with aberration effect of spherical mirror

•We need to develop the robust laser extraction part (stable girder) and design the optimized optical system.
•Laser propagation test and alignment for the 500-m-long straight section.