IP-BSM upgrade plan

2020.11.27

A. Aryshev, T. Okugi, N. Terunuma

Outline

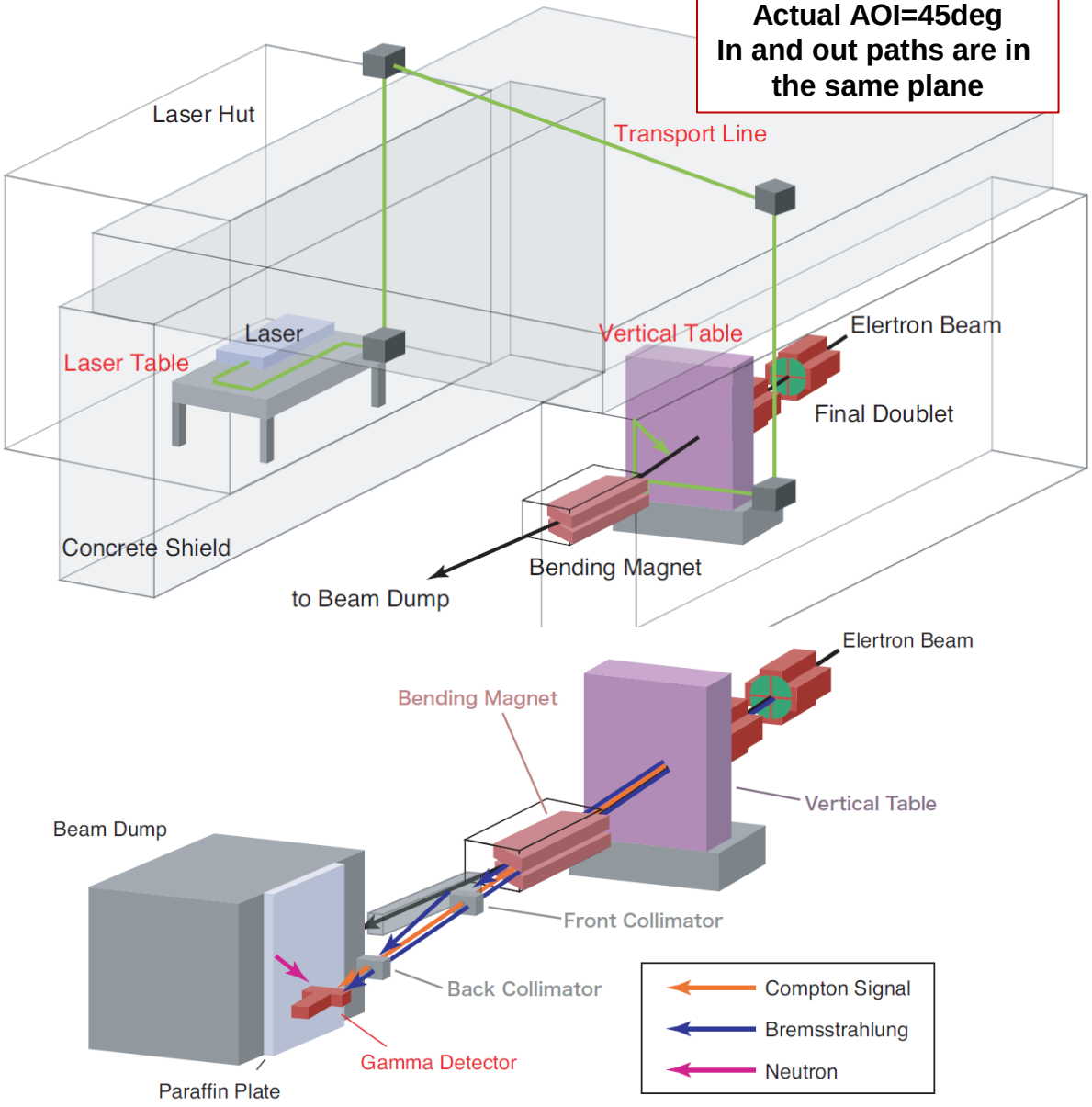
- IP-BSM overview
  - Nd:YAG laser
  - Laser hut
  - Vertical table
  - Expander-reducer, M2 measurements
  - Monitoring system
- Current problems
- Discussion on laser upgrade
- 2020 – 2021 plan

IP-BSM overview

This is schematics
Actual AOI=45deg
In and out paths are in the same plane

IP-BSM is not just a laser

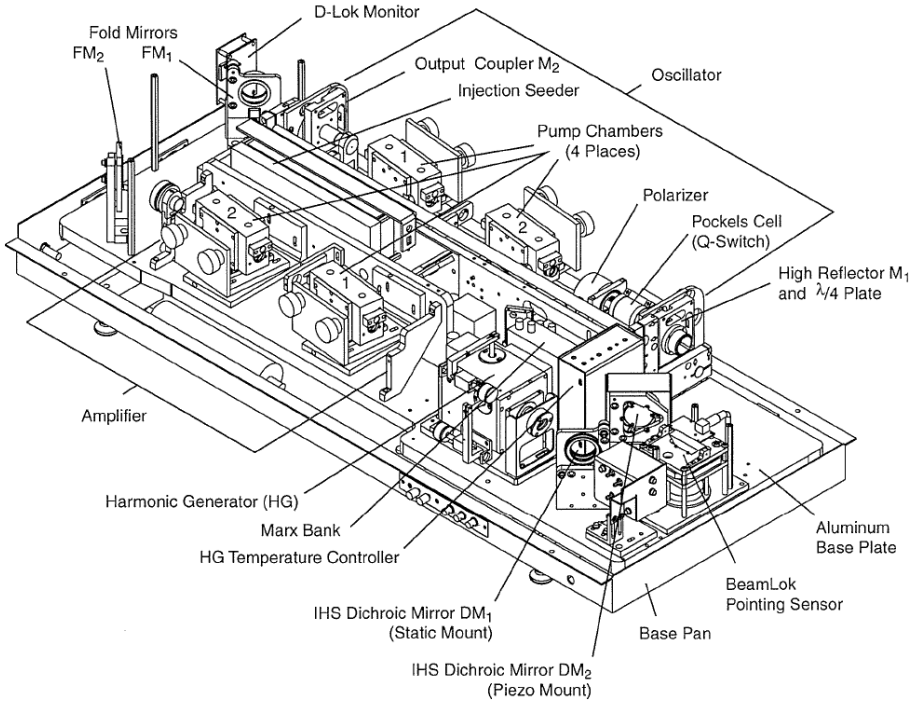
- IP-BSM consists of:
  - Nd:YAG Laser
  - Laser Transport Line (LTL)
  - Vertical table (laser FF-IP)
  - Detection line:
    - Collimator
    - Detectors
  - DAQ
  - Timing system
  - Software



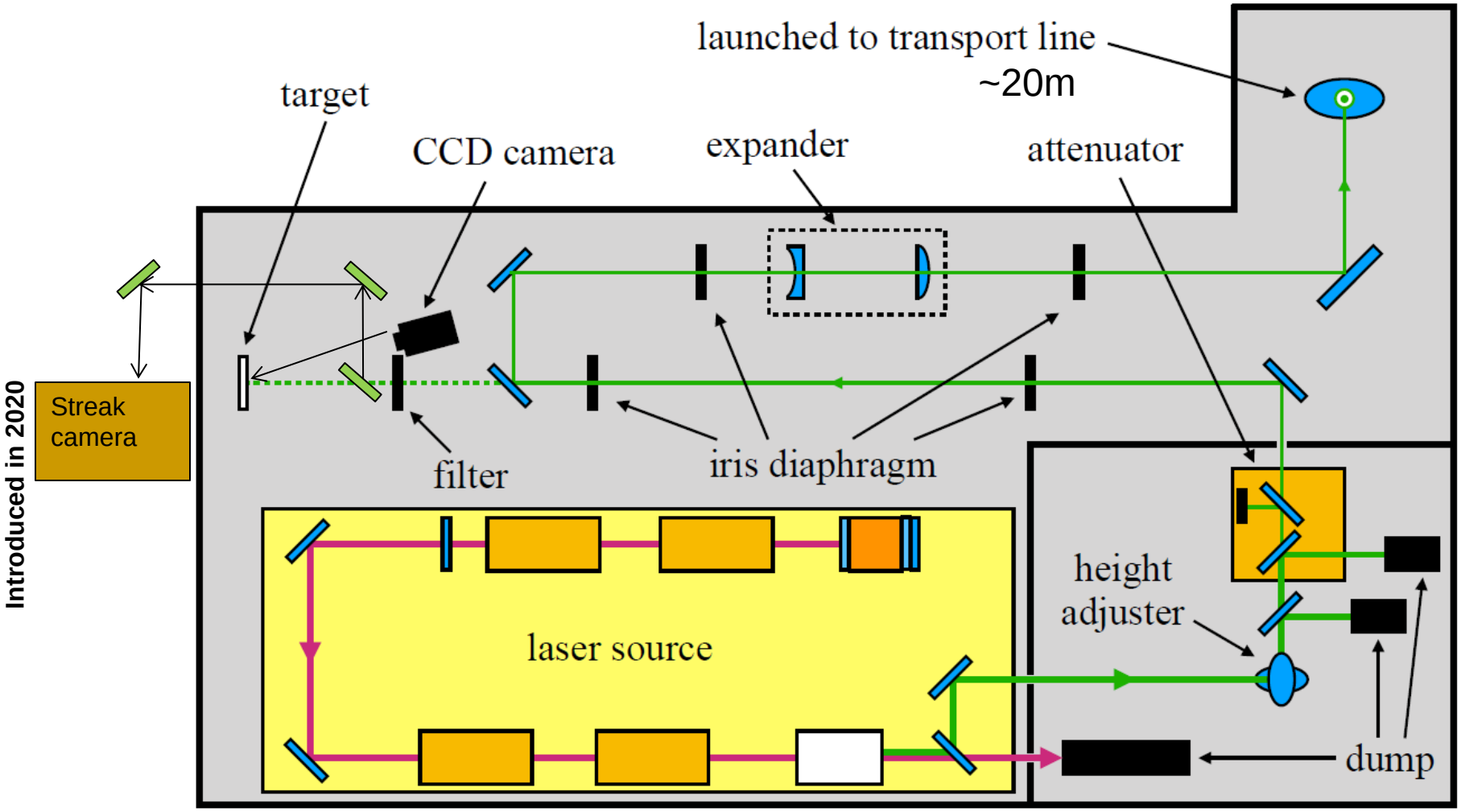
Spectra-Physics Quanta-Ray PRO 350

Right now it is discontinued

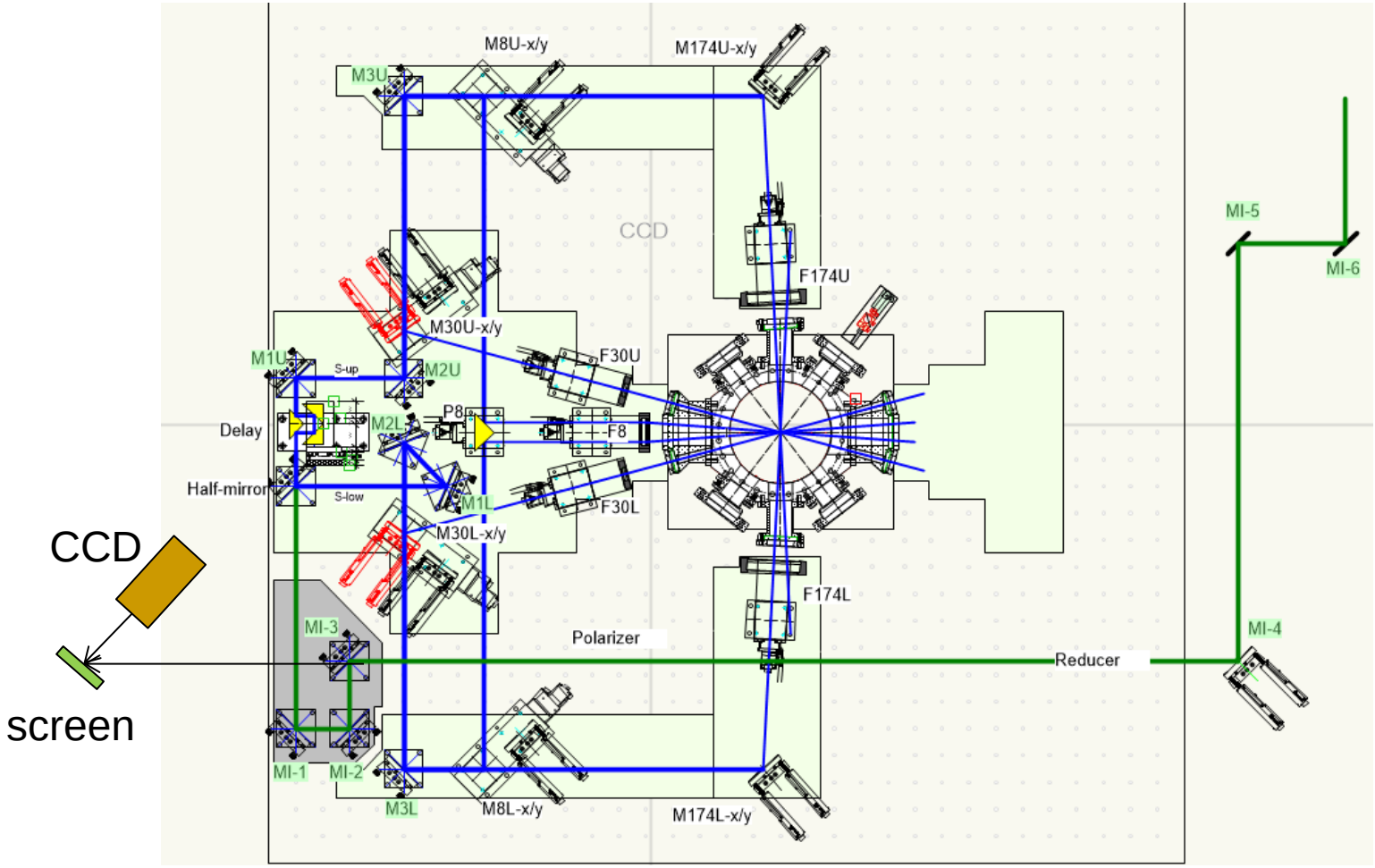
- **Company specs:**
  - Type: Nd:YAG Q-switched
  - E_{532nm} = 1.4 J +/- 3%
  - Pulse = 8ns +/- <0.5ns (FWHM)
  - Rep. rate = 6.24 Hz
  - M2 – will be shown below
- **Requires regular actions:**
  - Cleaning
  - Tuning
  - Flash lamps replacement



IP-BSM Laser hut

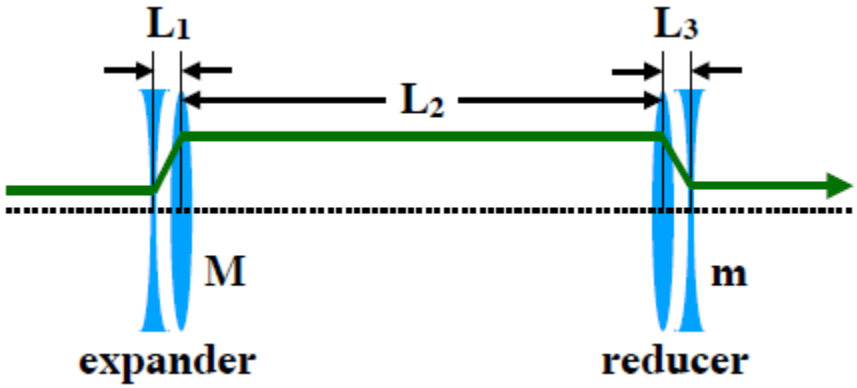


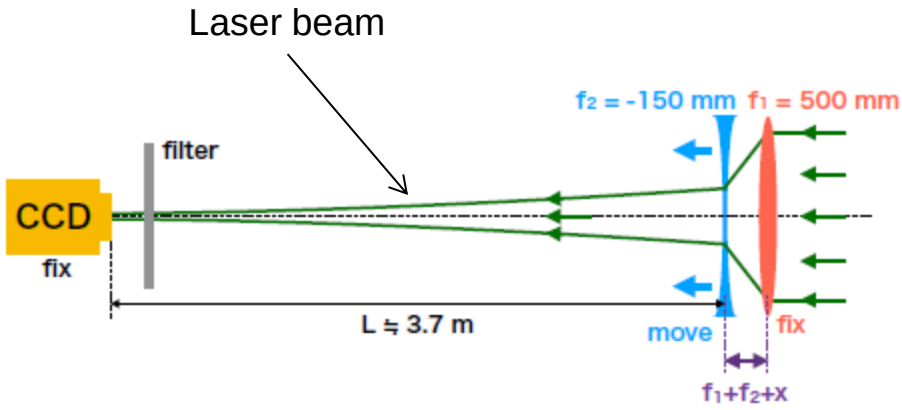
Vertical table



Expander – reducer, M^2 measurements

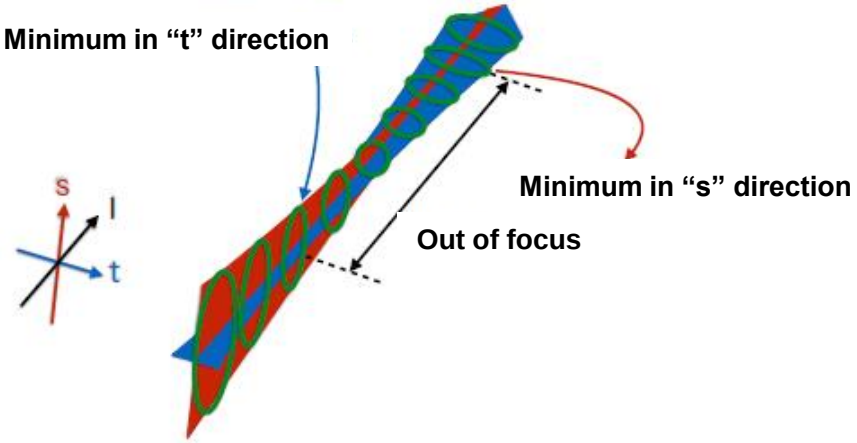
Existing laser transport line

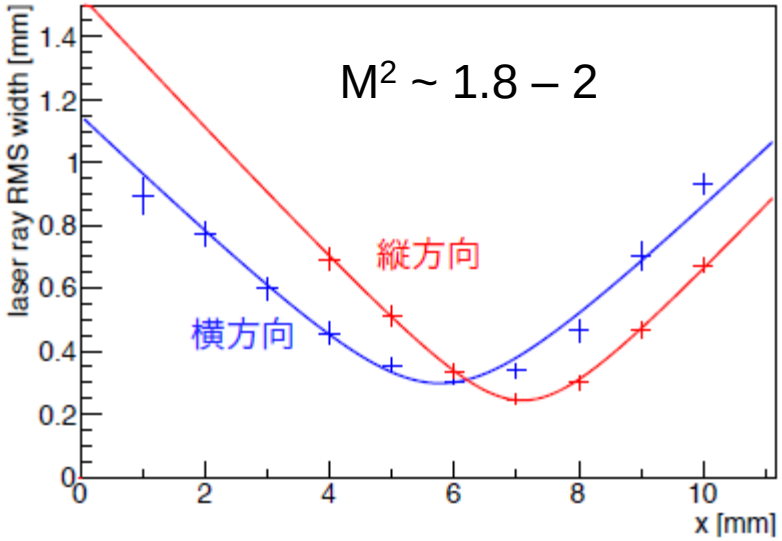




M2 measurement shows that laser beam is astigmatic

Example of a strong astigmatism





Monitoring systems

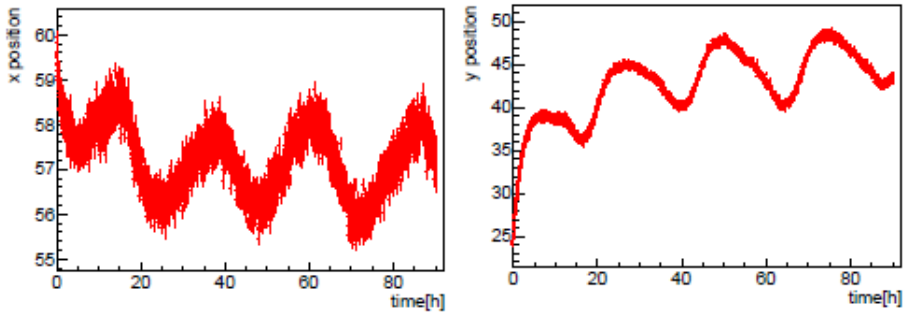
- Laser build-up monitor
  - General laser “health” monitor and laser tuning
- Energy meters (PD’s)
  - Real time normalization
- 2 CCD cameras (laser hut and Vert. table)
  - Transverse profile for LTL tuning
- Streak camera
  - Longitudinal profile monitoring
- IP screen
  - e-beam – laser initial overlap tuning
  - Resolution > 1um

- Mechanical references (LTL visual alignment)
  - Irises
  - Grid screens
- Desired
  - Fringe monitor (need development)

IP-BSM current problems

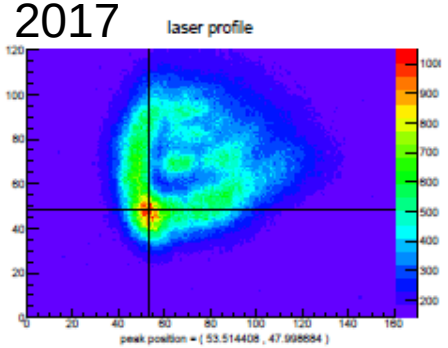
- Stability (Energy, Modes = fringe pattern)
- Laser beam parameters reproducibility
- Resolution
- Nd:YAG Laser aging (tuning, dust, etc)
- LTL and laser FF-IP tuning and optimization

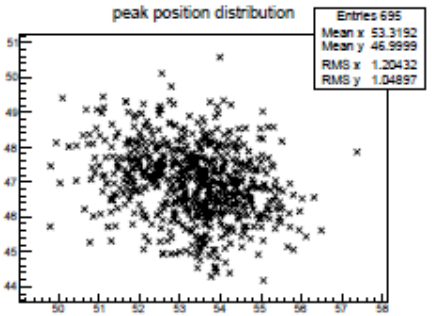
Pointing stability and aberrations



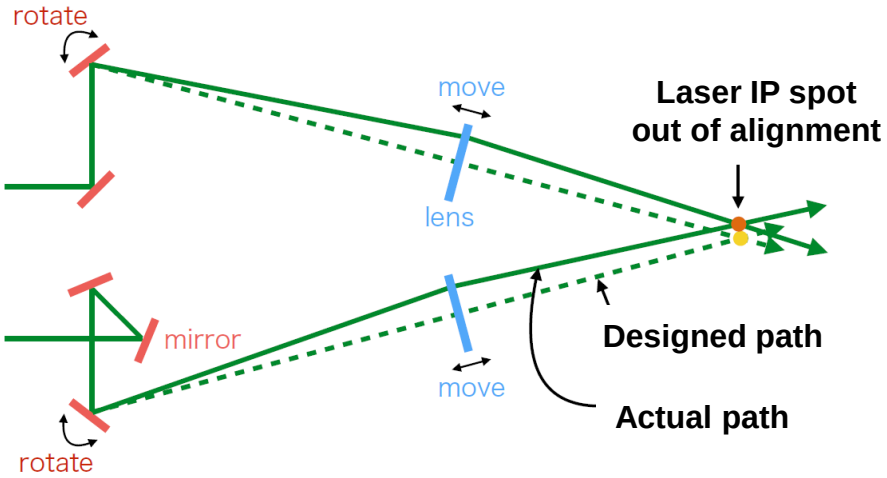
Profile is not the same time to time

2017

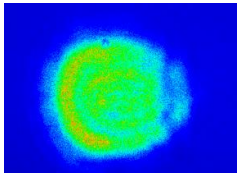


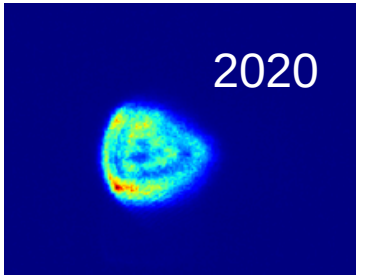


Not perfect laser path tuning result in aberrated profile at IP

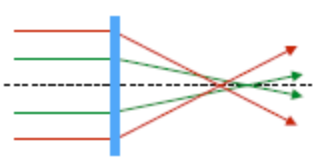


2017

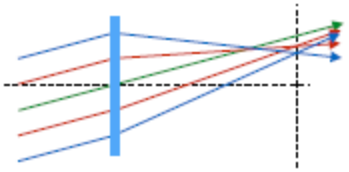




Types of aberrations we experience



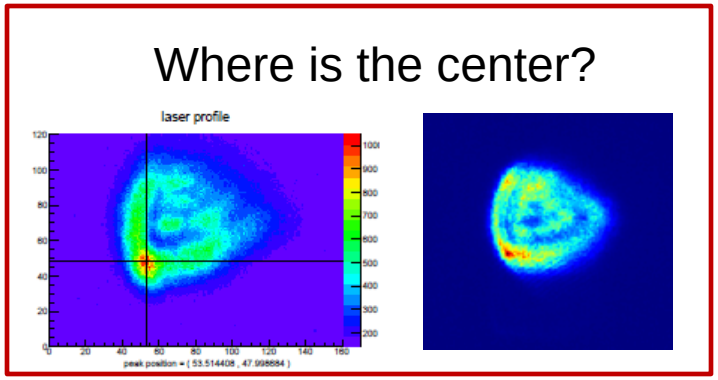
Chromatic



Coma

What can we do?

- Energy stability:
  - Pulse-by-pulse normalization already established.
- Pointing stability:
  - Should be studied.
  - mid- and long-term (hours and days) can be corrected by mirrors.
  - Need on-line position monitoring.
  - Need a solid reference (or simulation of the laser beam propagation to IP).
- Mode stability:
  - Laser tuning? or replacement?
- Fringe stability:
  - Need monitor (call for an R&D)



- Resolution:
  - Whole LTL and laser FF-IP simulation (ZEMAX or VirtualLab)
  - Upgrade of Expander-reducer, FF lens

Nd:YAG laser replacement choice

- **Gas and Dye lasers** are out of consideration due to bad mode stability and mode quality.
- **Novel types** (Thin-disk laser for example) are too futuristic and still very limited on the market.
- **Fiber lasers** (independent on doping element) have much better pointing and energy stability, but limited in energy per pulse (mJ level).
- **Ti:Sa laser** is good, but too short pulse duration (10^{th} fs – 10^{th} ps).

- **Nd:YAG:**
  - ps or ns (hence 10^{th} mJ or 100^{th} mJ per pulse) depend on e-beam arrival stability and ATF timing system
    - Hopefully we can measure that in 2021 ATF run
  - Single- or multi- mode type
    - We will consult with laser manufacturer
  - Wavelength (Harmonics of 1064nm: 532nm, 354nm, 266nm)
    - Need simulation, because actual handling difficulties may become stronger than benefits
    - Conversion efficiencies are different: 2^{nd} ~ 50%, 3^{rd} ~ 20%, 4^{th} ~ 35%
  - Pointing stability (typical for a new system) ~ urad
  - M2 (typical for a new system) ~ < 1.3
  - Ownership cost might be different for different systems

Nd:YAG laser potential suppliers

- https://ekspla.com/products/nanosecond-lasers/
- https://www.coherent.com/lasers
- https://amplitude-laser.com/products_category/standard-nanosecond-lasers/
- https://www.quantel-laser.com/en/products.html
- https://www.spectra-physics.com/

Nd:YAG laser replacement

- **Possible after**:
  - Complete understanding of all current problems
    - Maybe laser itself is good enough …
  - Finalization of new laser beam parameters:
    - Wavelength, Energy, Pulse duration, M2, Modes, Post production support, Maintenance cost, etc
- **Budget:**
  - ~ 150-200 kUSD (only laser system)
  - + 100kUSD (other optics upgrades and installation labor)
- **Procedure:**
  - We need to ask KEK directorate and/or Ministry for this kind of budget (just request preparation will take a few month).
  - We have to make an open call to potential suppliers.
  - Whole procurement may take about a year.

Meanwhile … (2020 - 2021)

- Start LTL, FF-IP simulation study (from Dec. 2020)
  - Analyze potential distortion effects
  - Propagate real laser wavefront (need wavefront monitor system) through simulation and compare it with measurements.
  - Re-design FF lenses
- Start laser stability study (from Dec. 2020)
- e-beam arrival and timing jitter ??
- Continue finalization of new laser parameters.