EOS-BPM FY22 Progress and Plans for FY23
FACET-II PAC Meeting

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EOS-BPM Overview

• Goal of EOS-BPM is to provide a non-destructive tool for measuring both transverse and longitudinal beam positions for each bunch on a shot-by-shot basis.
  • Theoretical Transverse Resolution of 1 µm
  • Theoretical Longitudinal/Temporal Resolution of 10 fs.
• A laser pulse within an EOS crystal will have its polarization rotated if the EOS crystal is also within the electric field of a passing electron bunch.
• One crystal can give info on bunch charge and timing
• Two crystals allows for the two signals to be compared, allowing for femtosecond time-resolved BPM capabilities.
EOS-BPM Hardware

TOP VIEW

EO Crystals: 1cm x 1cm in transverse plane, 1-5 mm from e-beam axis
EOS-BPM Hardware

Insertion mirrors

Extraction mirrors

EO Crystals

800nm probe

0.5" travel
motorized actuators

e-beam
Installed for the Summer Run

- One 1mm thick ZnTe crystal
  - High-Signal, Low-Resolution
- One 100 um thick GaP crystal
  - Low-Signal, High-Resolution
- Right: laser paths in red and e-beam path in blue dashed.
  - Cameras detect polarization rotation of the incoming probe laser due to the strength of the e-beam’s electric fields.
    - Signal position on camera corresponds to the timing between the laser and e-beam.
Timeline

- ZnTe installed in “EOS1” – March 15th
- Failed to shift with only EOS’s ZnTe – May 11th
- Axilens plasma to shift – June 10th
- ZnTe to shift – June 16th
- GaP installed in “EOS2” – June 27th
- GaP to shift – July 6th
- TCAV jitter study with GaP EOS – July 12th
  ...
- Installation of two GaP crystals – By December
- Commissioning of ‘BPM’ capabilities – By December
ZnTe and GaP Raw Data

- EOS signal window is 4 ps wide on the ZnTe crystal.
  - Right: e-beam signal with laser arriving earlier (top) to later (bot).
- Signal on GaP is more narrow (below)
Timing Calibration Study

Left image shows the stripe position on the GaP when we vary the laser timing using a digital. Right image fits this to a timing calibration. Across longer timescales, e-beam laser timing jitters by 48 fs rms.

- Femtosecond-to-Pixel Conversion Factor
  - $18.26 \pm 0.38$ fs/pix
Correlation between EOS and upstream PVs (C. Emma)

- EOS timing has been used to investigate sources of ToA jitter.
- Right: correlation plots between EOS (y axis) and various PVs.
- Strong correlation with energy BPMs but also horizontal and vertical BPMs in LI14/LI20
  - Dispersion leaking out of compressors?
EOS Goals Going Forward

- Continue supporting FACET-II user experiments with the ‘EOS’ aspect by measuring the shot-by-shot relative timing between the laser and the electron beam.
- Commission the ‘BPM’ aspect after installing two GaP crystals by being able to measure transverse offset of an electron beam and comparing to existing BPM’s.
- Improve analysis tools and make such software available to users.
- Demonstrate capabilities of resolving the longitudinal separation between drive and witness bunches in two-bunch operation.
Thanks!

Any Questions?
Publication on the EOS-BPM Design:
https://doi.org/10.1016/j.nima.2021.165210

Collaborators:

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Looking at how we can change the mounting of the crystals to better protect them from nearby work.

Since this picture was taken, the GaP crystal has passed away from a collision with a ball driver…
First ZnTe Signals

Left: First EOS signal due to e-beam. This image was with the laser about 0.5 ns after the e-beam.
Right: Timing in the laser using the electronic timing delay.
With the TCAV running and deflecting the beam onto DTOTR2, we attempted to see if there was a correlation between TCAV deflection and TOA at the EOS.
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**Non-Correlated Data Set**

**DTOTR2**

**DAQ 01564**

**Corr : NaN**
Measurement of EOS ToA jitter (C. Emma)

RMS jitter between electron beam and laser = 2.8 pix * 17 fs/pix = 48 fs
RMS timing jitter between e-beam and TCAV = 61 um = 200 fs.
That’s 4x larger than the laser to e-beam jitter on the same data set
Additionally, we were able to make a collection of datasets with varying GaP – beamline spacing. Top is ~1 mm to beamline and is much brighter than bottom, ~4.5 mm to beamline. Had to vary both EOS stage position and electronic laser delay, so data is spread out over multiple shots.