Collaboration Study of Coherent Optical Transition Radiation Effects on Profile Screen Measurements

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ARIES

Joint ARIES-ADA Workshop on 'Scintillation Screens and Optical Technology for transverse Profile Measurements'

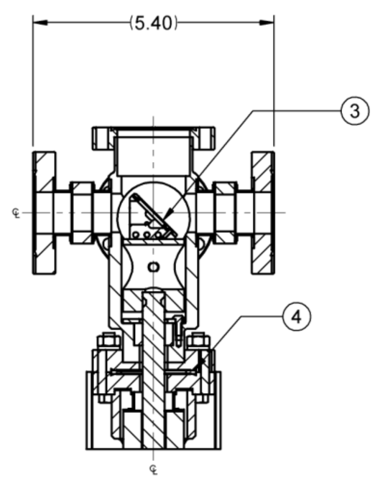
Statement of the problem

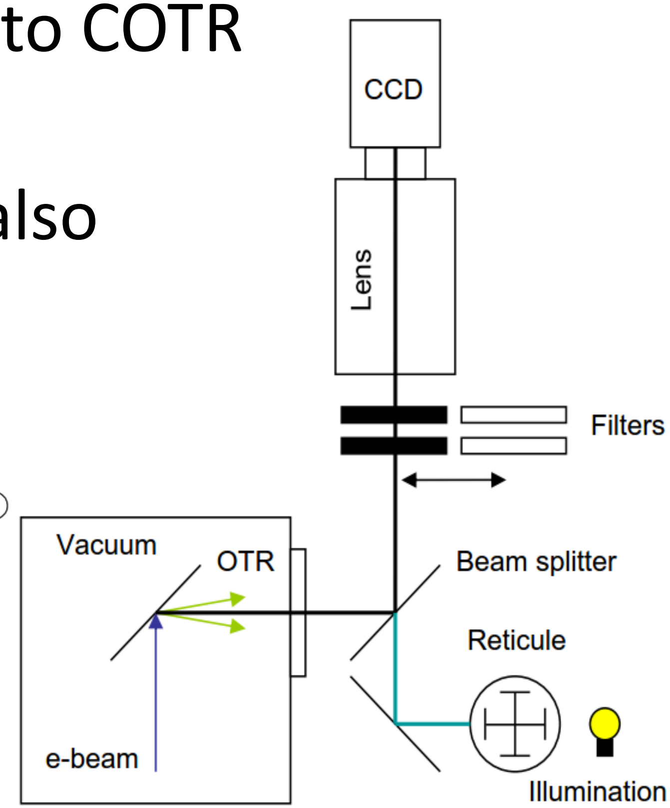
- Linac based FELs produce ultra-short bunches with low longitudinal emittance (energy spread)
- High peak current (kiloAmps) and microbunching instability conspire to generate Coherent Optical Transition Radiation COTR at the surface of all screen materials.
  - e.g. 100 pC in 1 fs is 10 kA
- The OTR becomes Coherent when the microbunch length is ~ radiation wavelength.
- The *brightness* of COTR is $\propto N_e^2$

  While brightness of OTR and fluorescence is $\propto N_e$
- So COTR is both unstable and many orders of magnitude brighter, making screens unusable.

Original LCLS profile monitors

- All OTR foil screens downstream of the first injector bend were unusable due to COTR effects
- YAG screen with same geometry also swamped by COTR





Abandon LCLS profile monitors

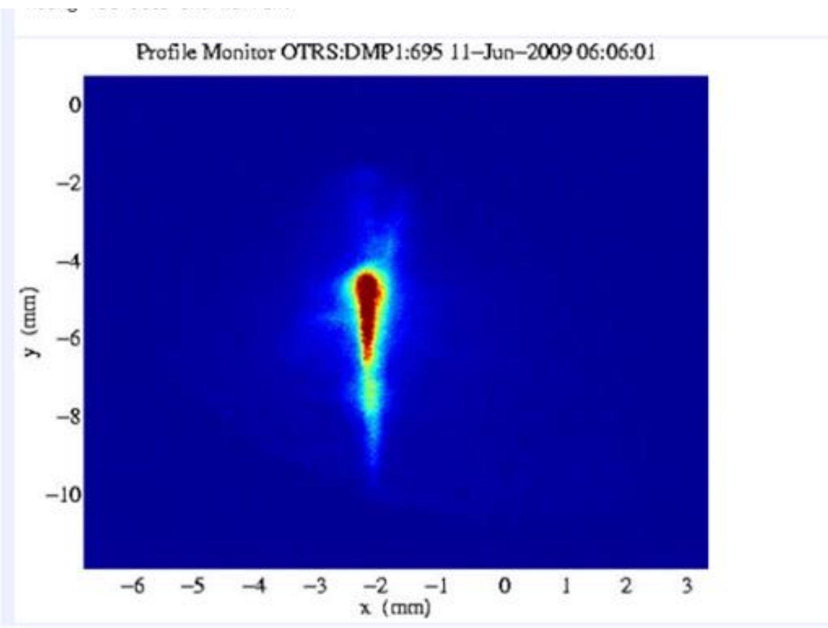
- Routine transverse emittance measurement now done with fast wire scanners
- Except for YAG screen at the injector, upstream of bunch compressors
- And at the undulator dump screen, where single-shot measurements are essential

Example of COTR seen at LCLS spectrometer undulator dump

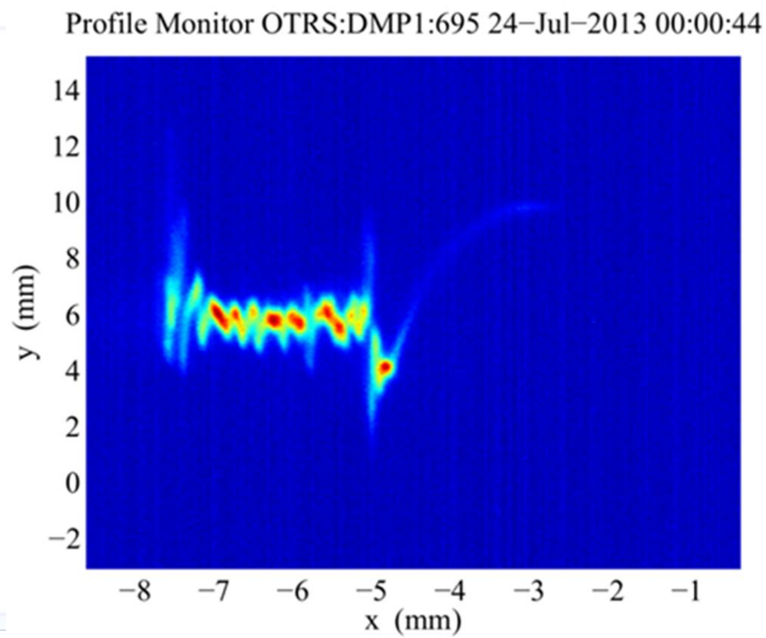
Image uncorrelated to transverse beam size

Micro-bunching directly observed with XTCAV

Streaked image of longitudinal phase space

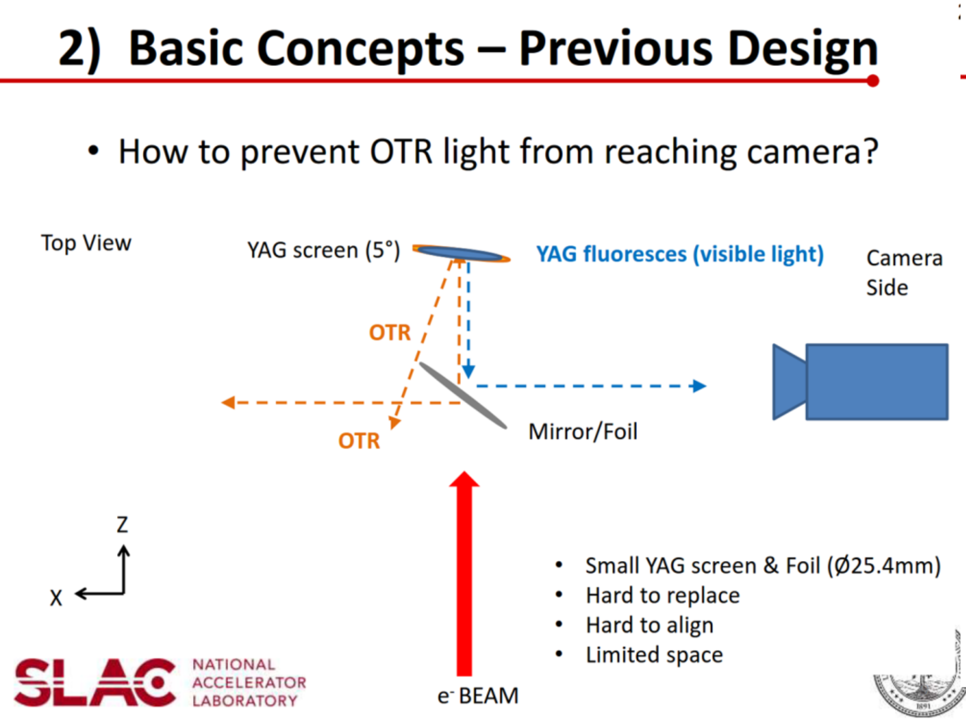


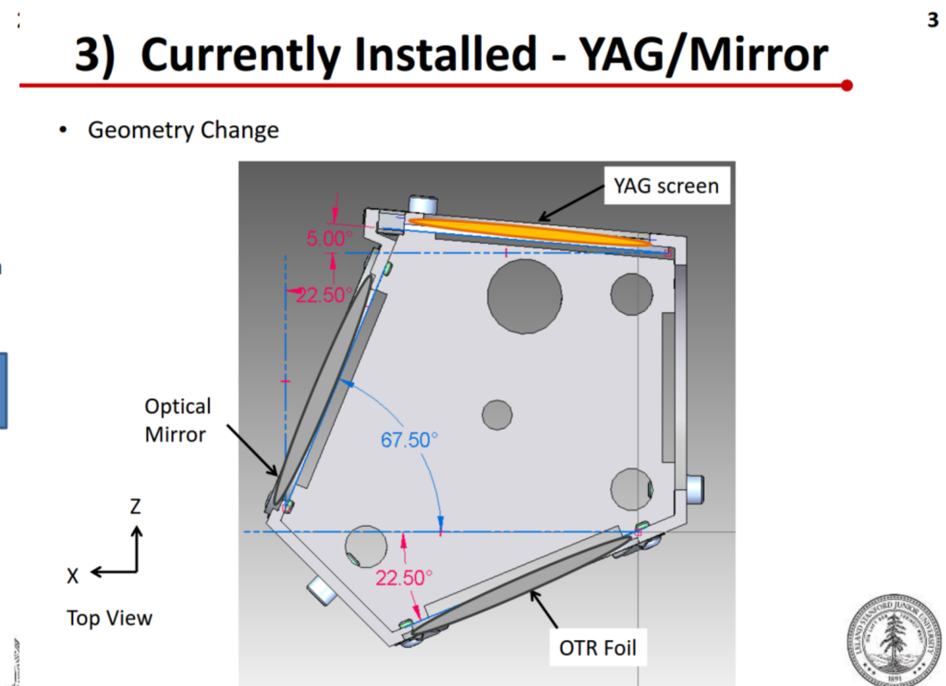
Original dump screen



New dump screen plus deflector cavity

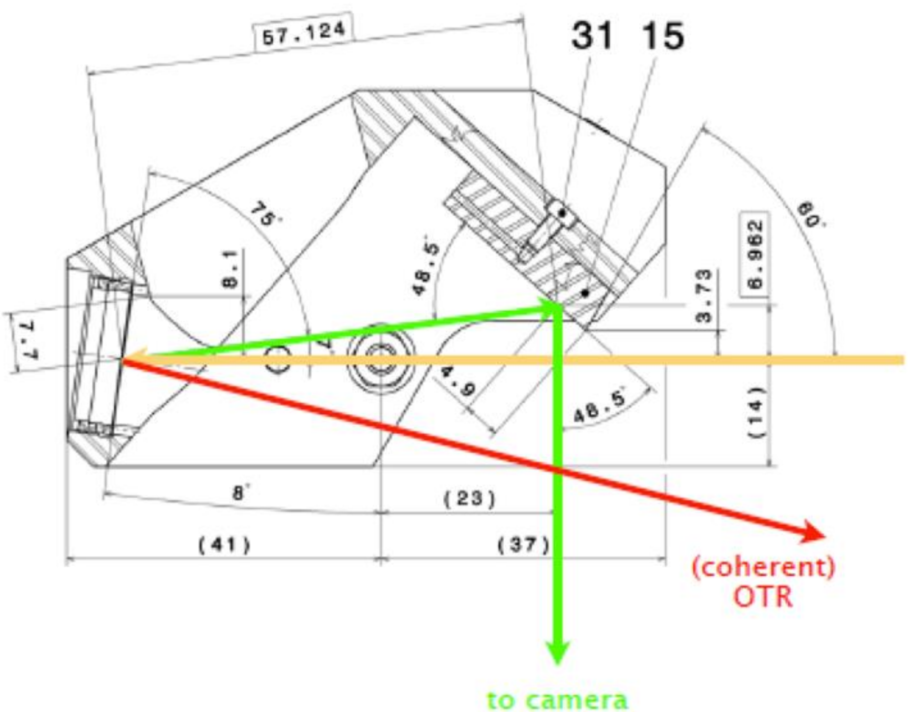
First iteration in design to suppress COTR at the dump





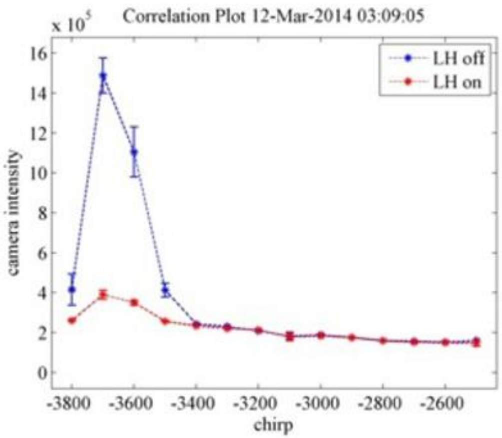
Second design iteration developed at PSI by R. Ischebeck

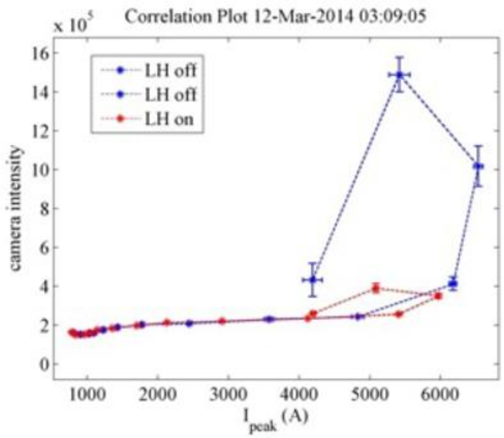
- Resolution preserved using Snell-Scheimpflug geometry

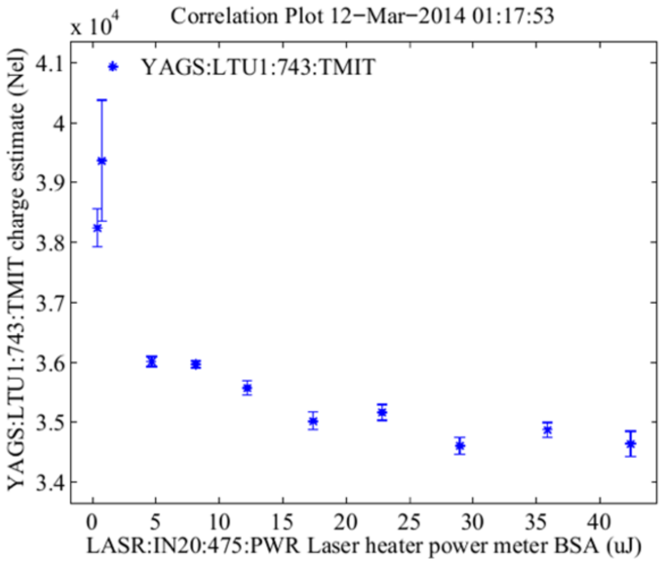


PSI-YAG successfully tested at LCLS

- Screen intensity vs. peak bunch current
- And screen intensity vs. laser heater excitation

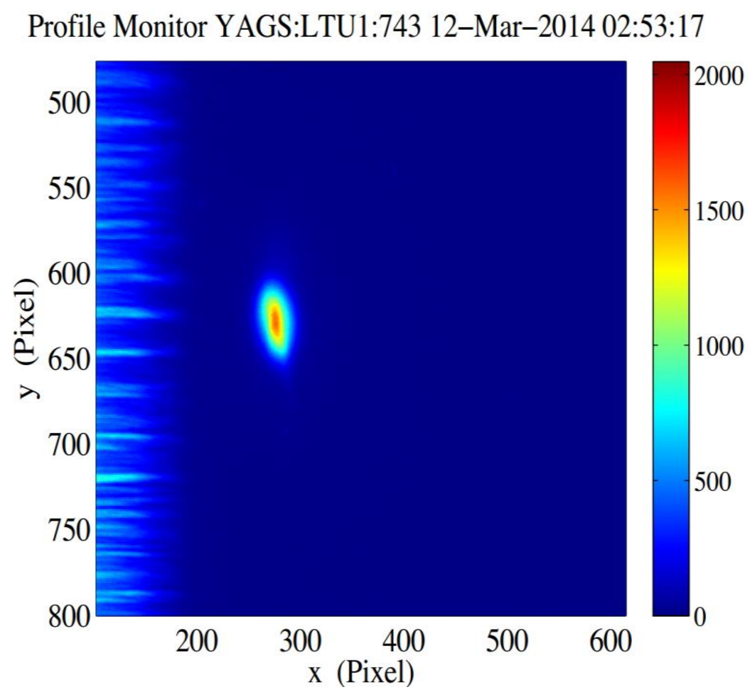


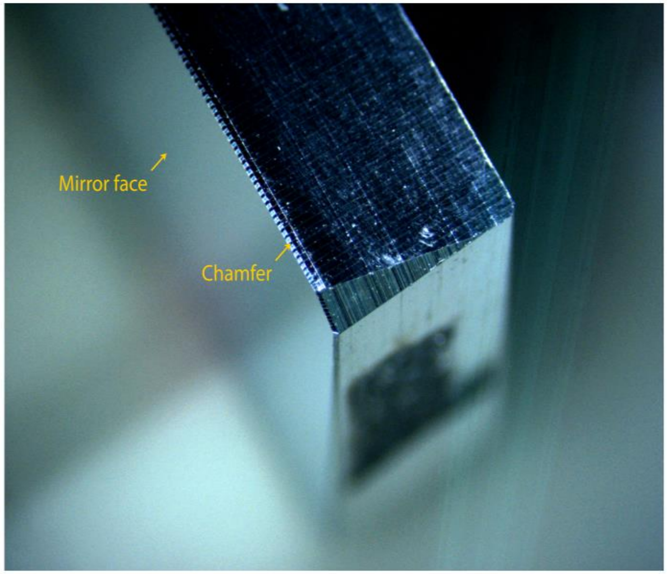




PSI-YAG Prototype limitations

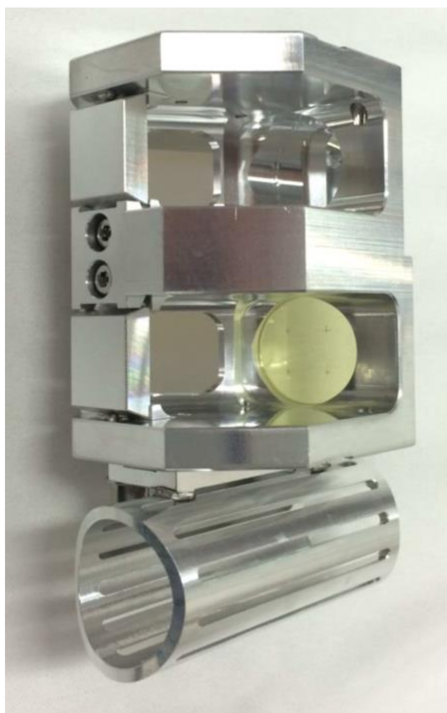
- Some CDR still observed from edge of mirror 3 mm away from beam axis

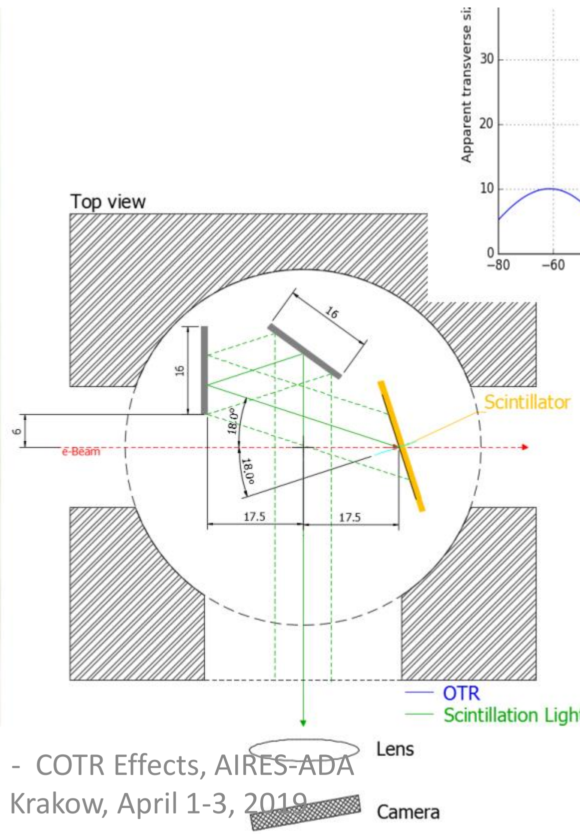




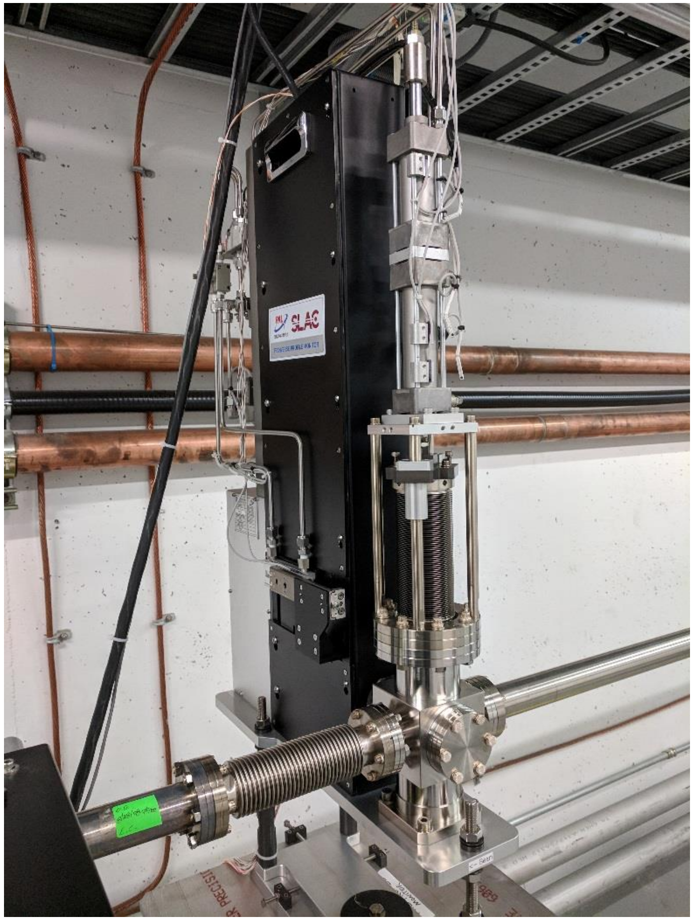
Third design iteration developed at PAL by C. Kim

- Add a second in-vacuum mirror to increase distance from beam axis to 5mm





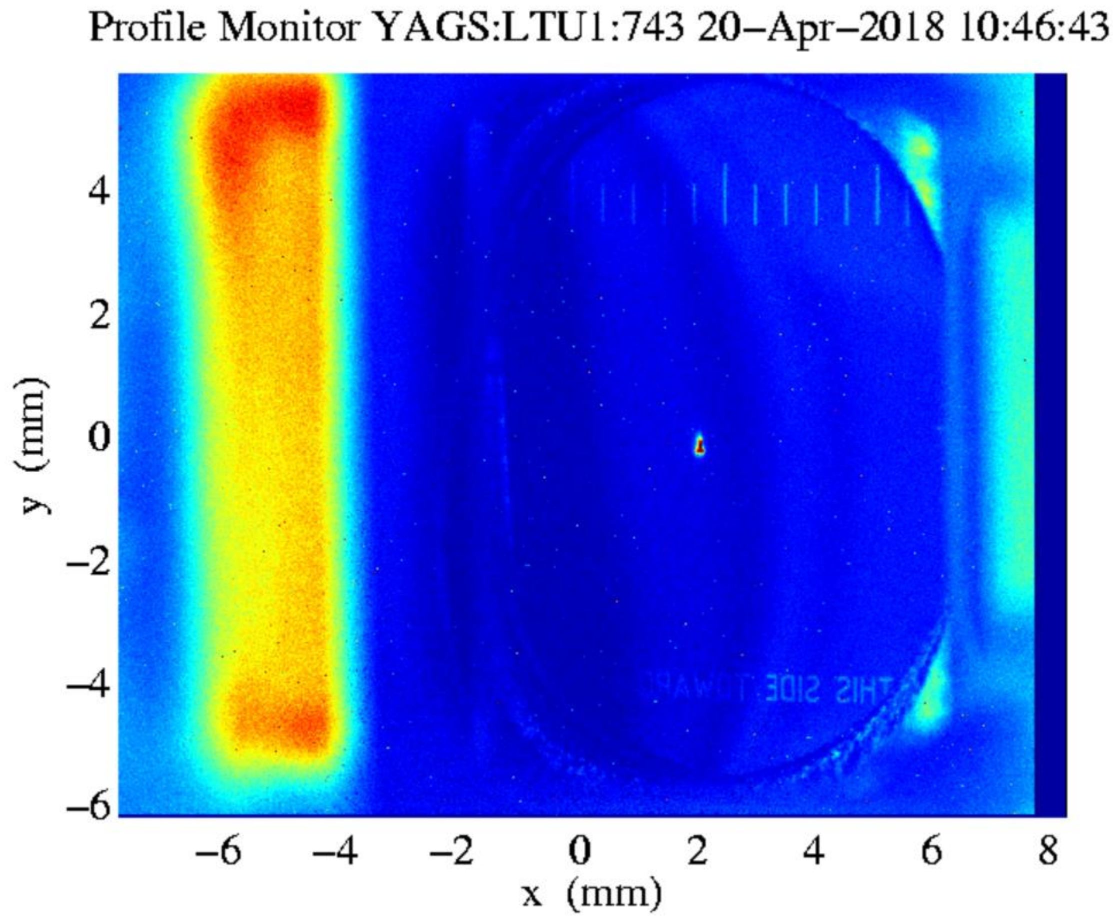
PAL-YAG successfully tested at LCLS



Advantages of the PAL-YAG

- Suppression of COTR
- 3-position actuator for YAG, OTR or wakefield shield
- Commercially available from Korean manufacturer
- Well engineered design with integrated optics, filters, illumination, limit switches etc.

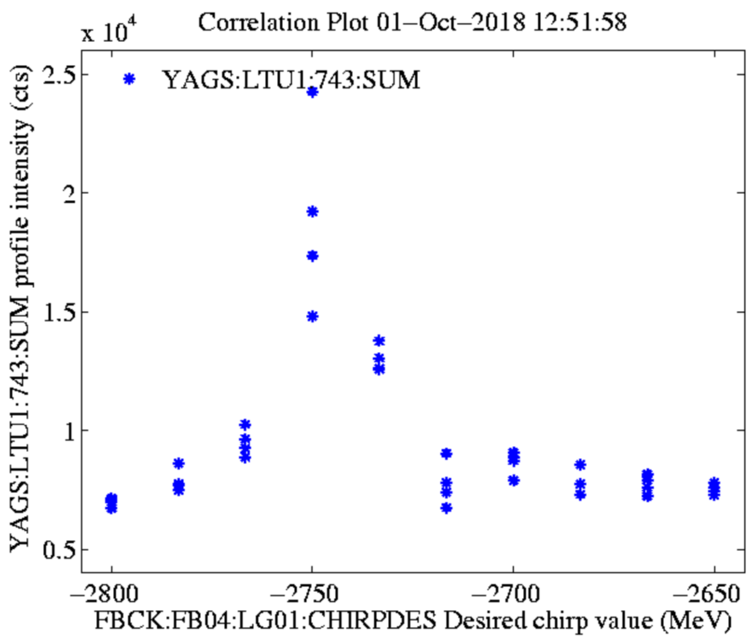
PAL screen image does not exhibit any edge radiation from mirror edge



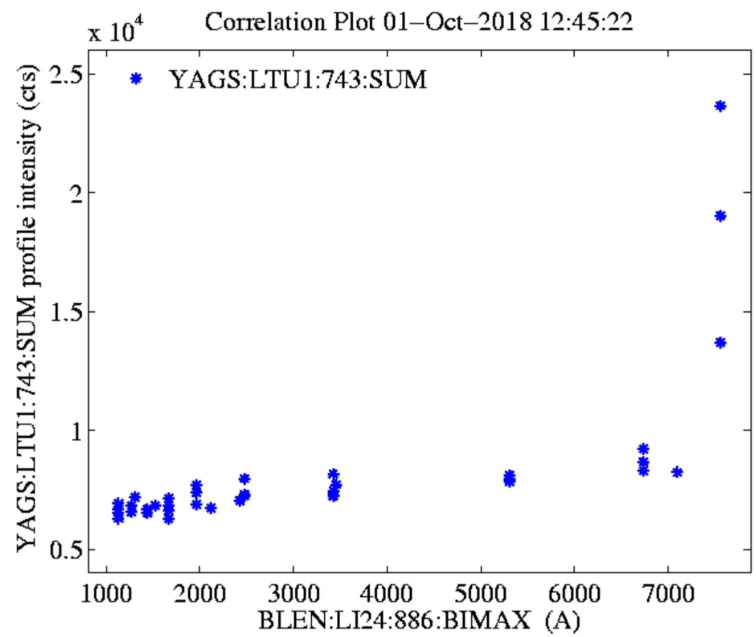
PAL Monitor: Worst case – LH off

fully compressed sees factor ~3 enhancement only,
compared to ~10 with previous PSI YAG

Camera intensity vs. Bunch compressor chirp



Camera intensity vs. Bunch compressor peak current



Conclusions and Challenges

- COTR can be successfully suppressed while maintaining good optical resolution with correct design geometry.

- Next challenge
- Make screen measurements less invasive to FEL user operation
  - Need YAG screens <<50 um thickness and 20 mm diam. To minimize beam loss.
- Note, we also observe YAG radiation damage effects with prolonged exposure to electron beam

Acknowledgements

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  - Rasmus Ischebeck at PSI
  - Changbum Kim at PAL
  - And the accelerator team at SLAC
- And many thanks to the Workshop organizers for this opportunity to discuss these issues