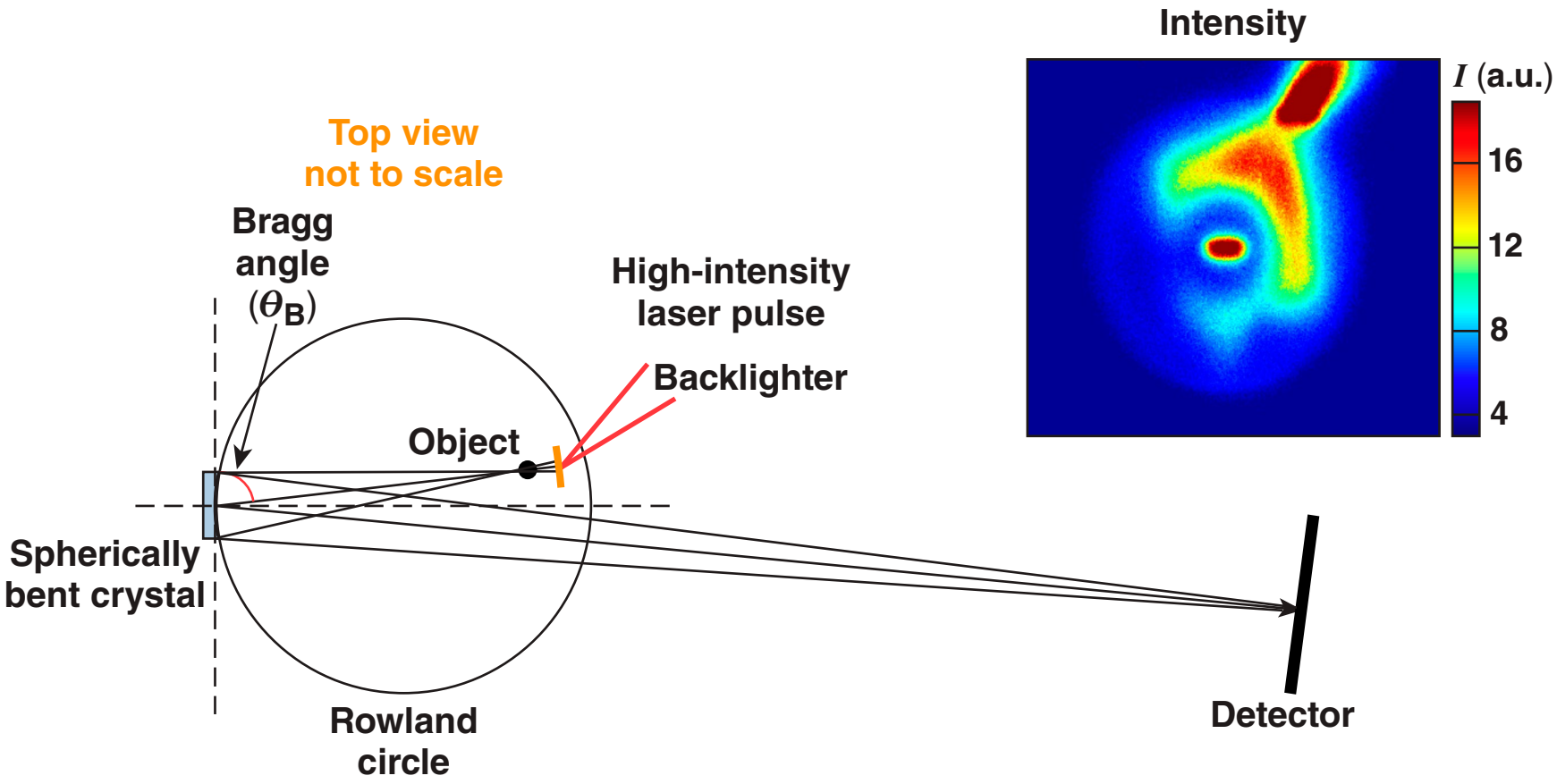
Soft X-Ray Backlighting of Direct-Drive Implosions Using a Narrowband Crystal Imaging System



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Summary

A spherical crystal imager (SCI) will be used to backlight cryogenic DT implosions on OMEGA

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- An SCI system is well suited for cryo backlighting because of its narrow spectral width, high throughput, and potential for high spatial resolution
- The backlighter is driven by an OMEGA EP short-pulse beam to provide high brightness and a high time resolution
- The first experiments with room-temperature CH targets showed encouraging images with an astigmatism-limited resolution of ~20 μm
- Two major improvements are planned for the Si-SCI on OMEGA
  - an aspheric crystal will be used to reduce the astigmatism
  - a fast target insertion system will make the SCI compatible with cryogenic operation

Collaborators

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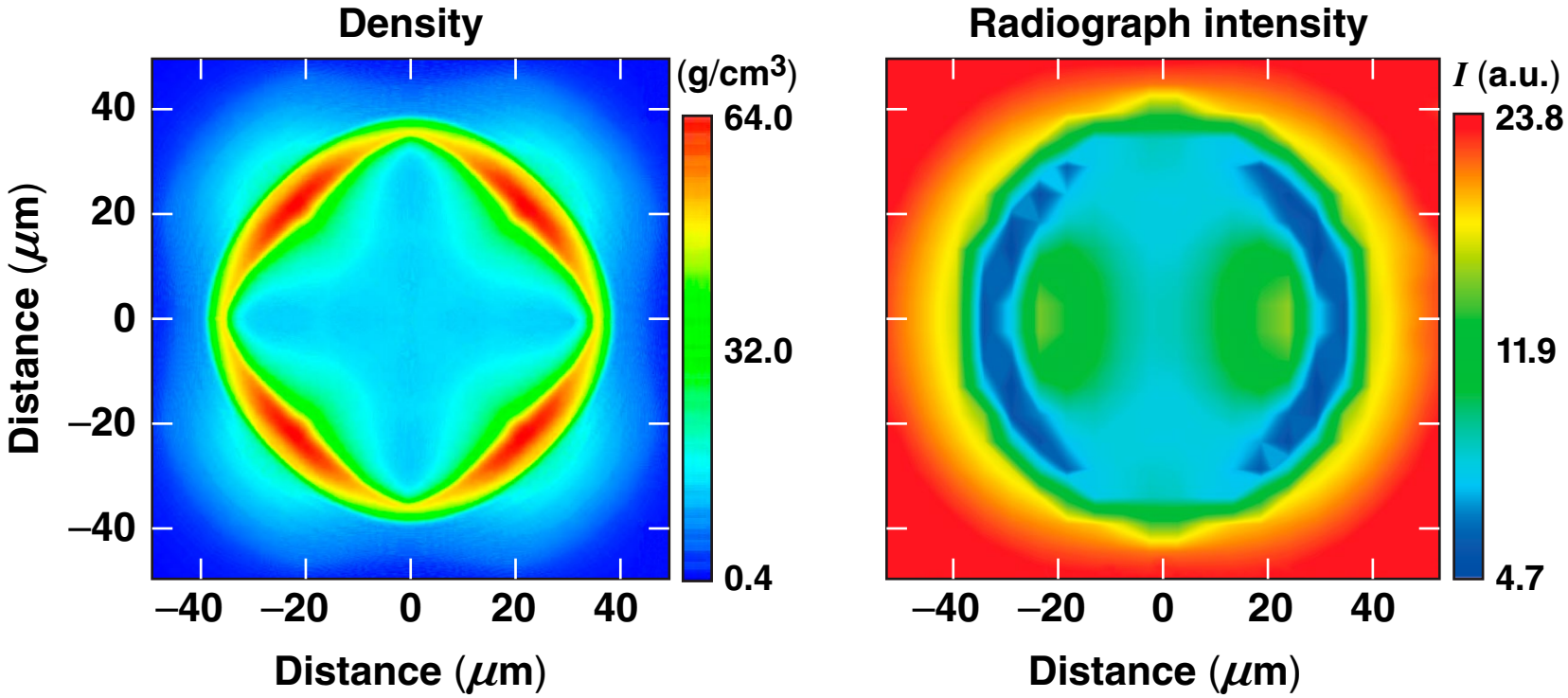
A high backlighter spectral brightness at 2 keV is required to image the compressed core of cryogenic targets

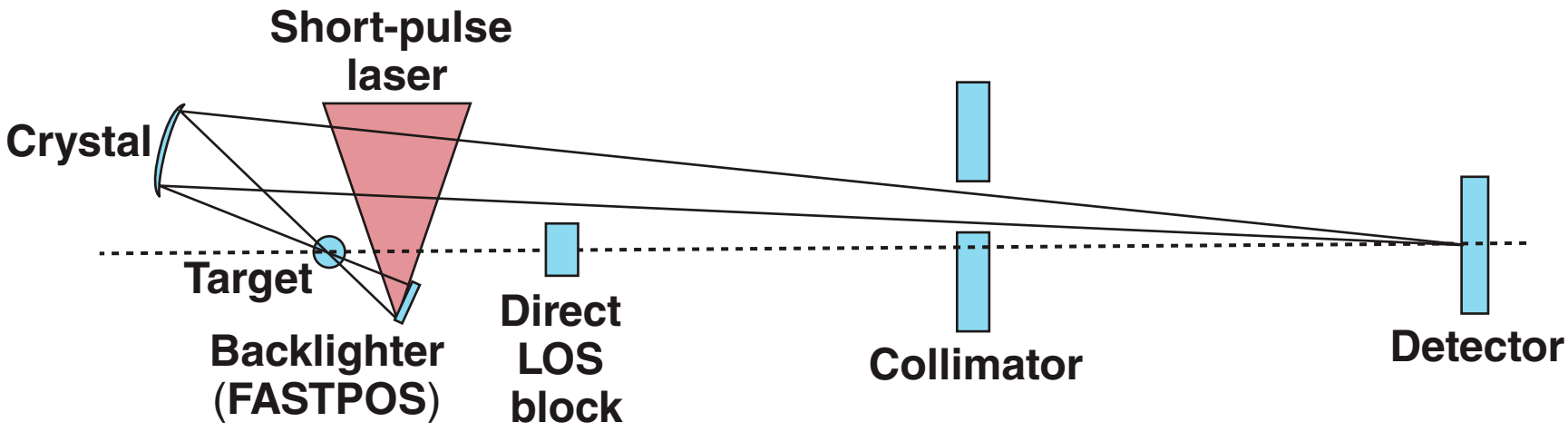


- Simulations predict a self-emission of 8 μJ/eV/ps/Sr in the 2-keV range
- The simulation assumes, for the backlighter, a 3-keV Planckian spectrum filtered in the 2- to 2.2-keV spectral range (~60 μJ/eV/ps/Sr).

Backlighting the compressed core of a cryogenic target implosion is challenging

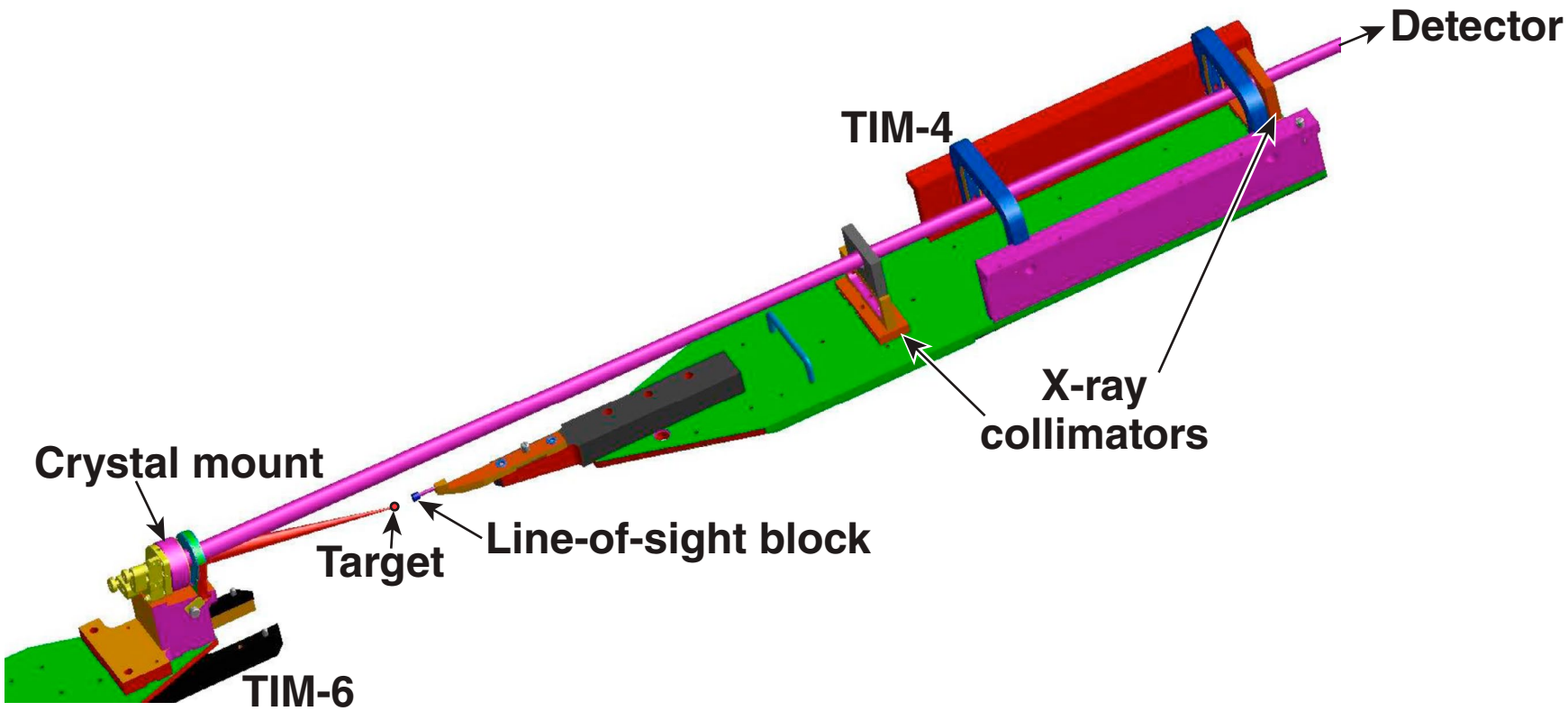
- The low opacity of DT requires a soft x-ray backlighter
  - the sperical crystal imager uses the Si-He$_\alpha$ line at 1865 eV
- A bright backlighter is required to overcome the self emission
  - the high energy (~1500 J at 10 ps) of OMEGA EP makes it possible to illuminate a large target area at intensities of ~10^{18} W/cm^2
- The cryo implosion evolves at high speed
  - the short-pulse duration of OMEGA EP provides a time resolution of the order of 10 ps
- The small size of the core requires a high resolution (<10 μm)
  - a crystal on an aspheric substrate has a calculated resolution of close to 1 μm

High-quality backlit images of implosions can be obtained with a crystal imaging system



- The backlighter foil is not in the focus of the imaging system, so the backlighter uniformity does not depend on the laser-intensity distribution
- A collimator blocks the line of sight (LOS) to the backlighter, minimizing the background from the short-pulse laser
- A direct LOS block shields the detector from background produced by the implosion target

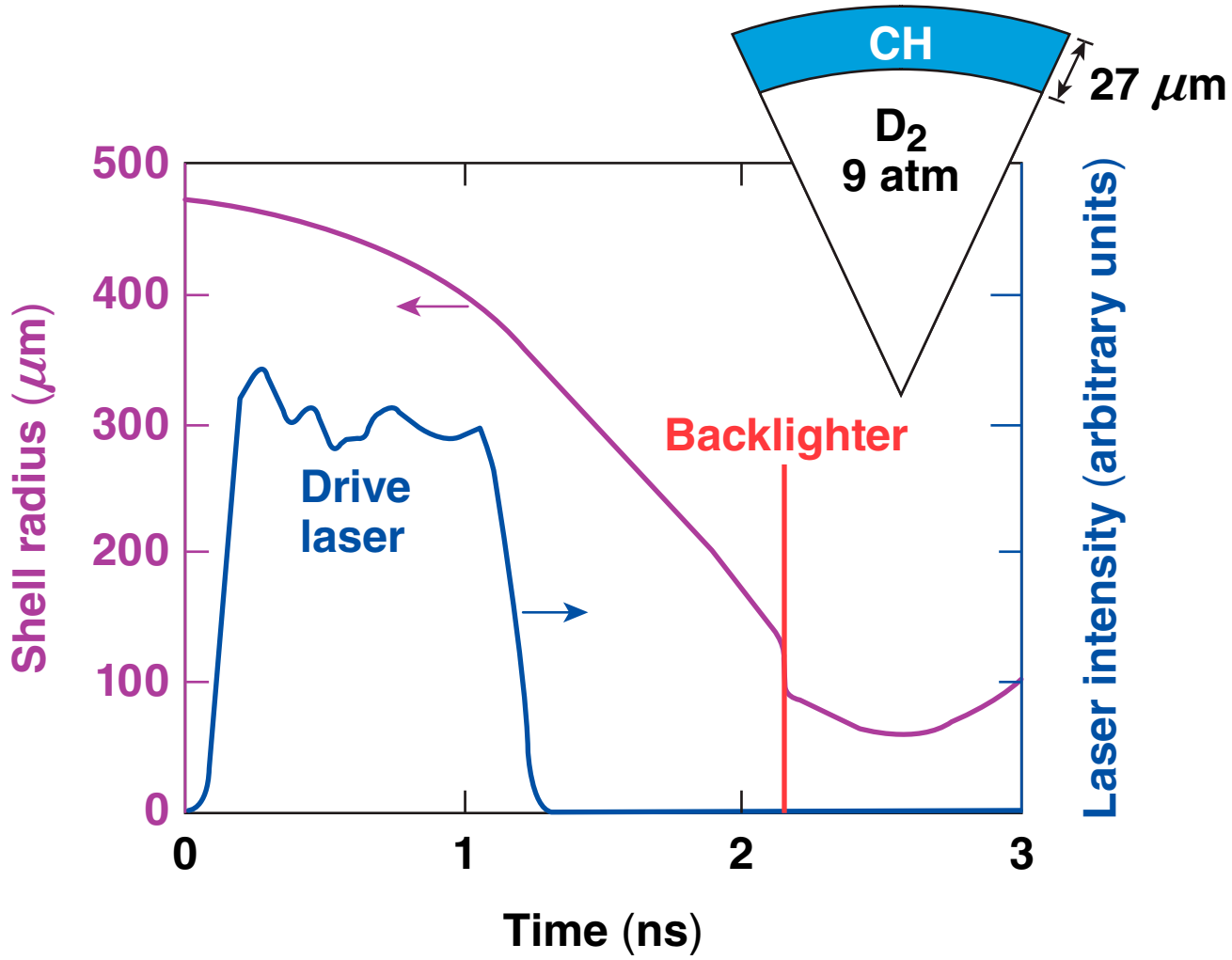
The OMEGA spherical crystal imager* is based on the OMEGA EP** design



- The crystal is located in TIM-6, 267 mm from the target
- The detector in TIM-4 is placed 3.6 m from the crystal for a magnification of ~15

*C. Stoeckl *et al.*, Rev. Sci. Instrum. 83, 10E501 (2012).
**C. Stoeckl *et al.*, Rev. Sci. Instrum. 83, 033107 (2012).

First tests of the Si He$_\alpha$ SCI system were performed with room-temperature, gas-filled CH target implosions



- Plastic is completely opaque to Si He$_\alpha$ near peak compression

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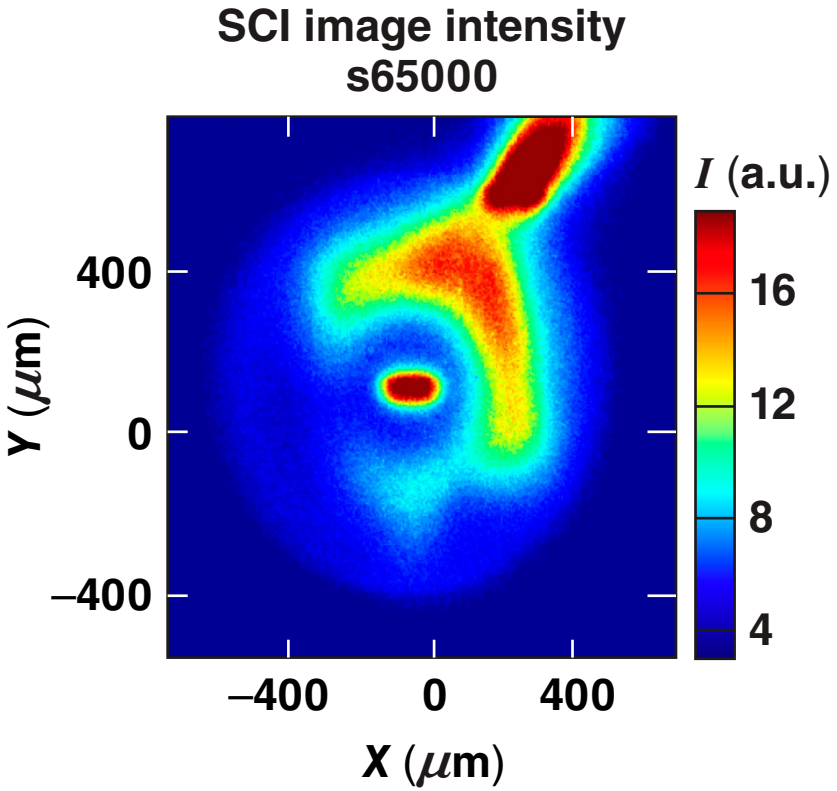
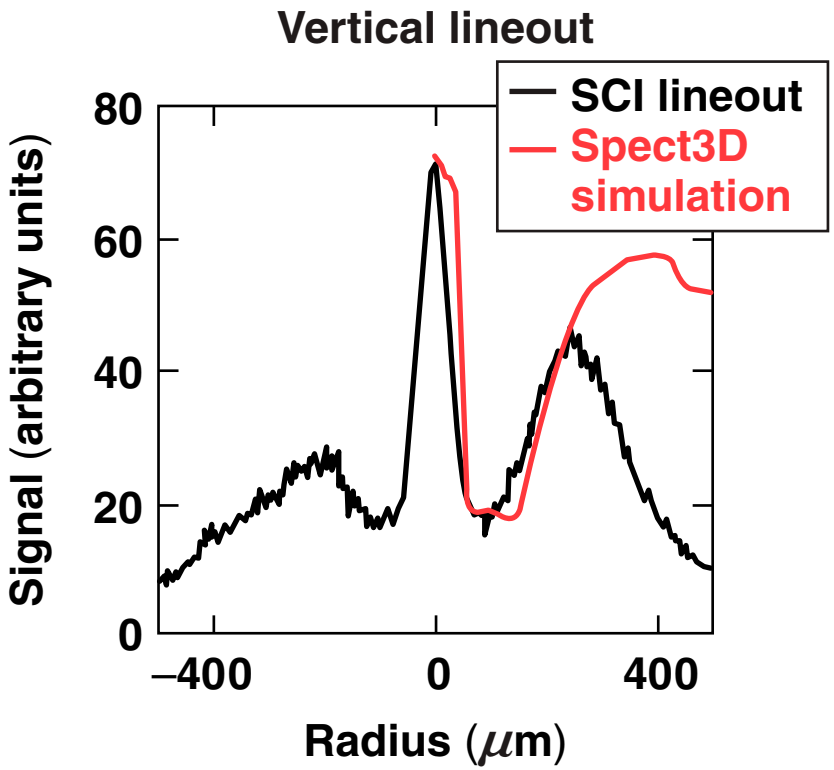
Reasonable agreement is achieved between the experimental image and Spect3D

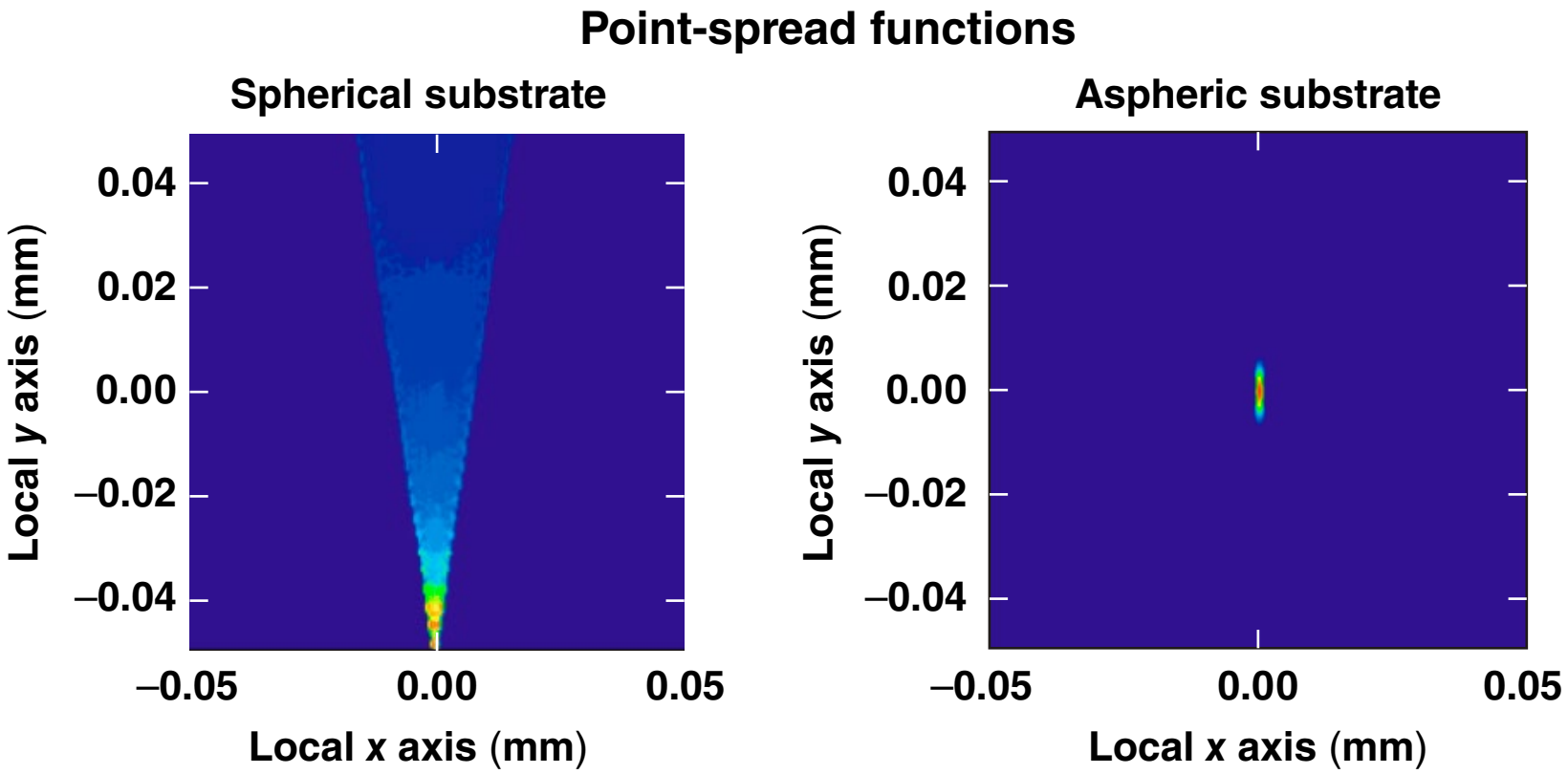




- Higher-order reflections must be included in Spect3D* simulations to reproduce experimental images

*J. J. MacFarlane *et al.*, High Energy Density Phys. 3, 181 (2007).

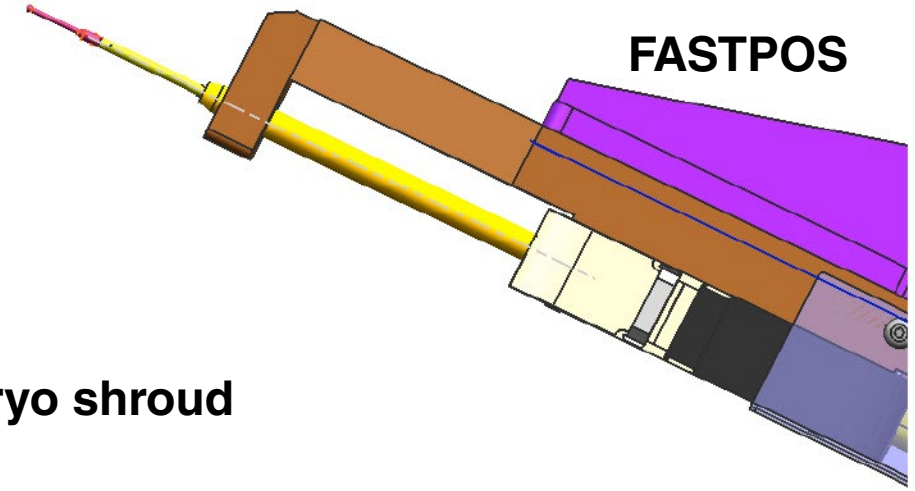
An aspheric crystal substrate has been designed to reduce the aberrations of the crystal imager



- The design of the aspheric substrate uses five aspheric terms to reduce the astigmatism, coma, and fourth-order horizontal aberrations

A fast target inserter (FASTPOS) is available to insert the backligher target once the cryo shroud is removed

- The backlighter target must be positioned <10 mm from the cryo target, which is inside the shroud envelope
- FASTPOS has demonstrated the required
  - speed (<100-ms insertion)
  - accuracy (<50 μm)
  - electromagnetic interference resilience



Cryo shroud

Summary/Conclusions

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