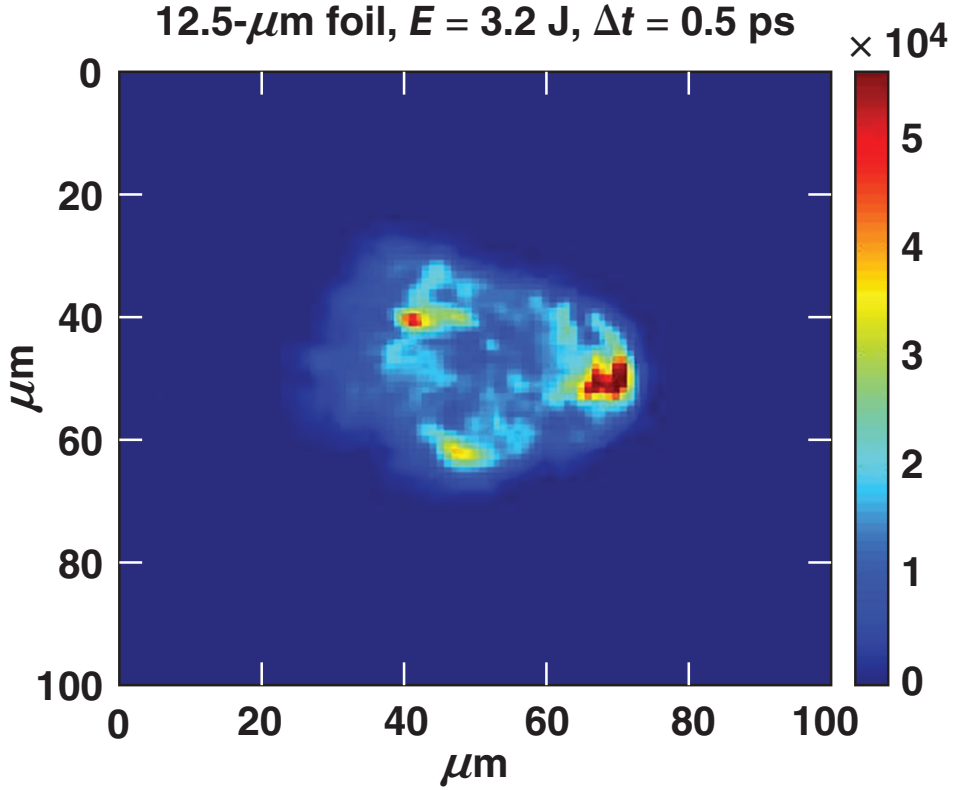
High-Resolution Imaging of Filamentary Structure Using Optical Transition Radiation



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Summary

Filamentation of relativistic electron beams will be diagnosed with high resolution using coherent transition radiation (CTR)

UR LLE

- A transition radiation diagnostic (TRD) is being developed on LLE's multiterawatt (MTW) laser ($I \sim 2 \times 10^{19}$ W/cm^2).
- Measurements of the optical performance suggest submicron resolution can be obtained.
- Calculations suggest a promising signal to background of 10 → 100.

Initial experimental results show strong 2ω signals containing 2-μm structures emitted from the target rear side.

Collaborators

UR LLE

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Coherent transition radiation provides information on the dynamics of relativistic electron beam transport

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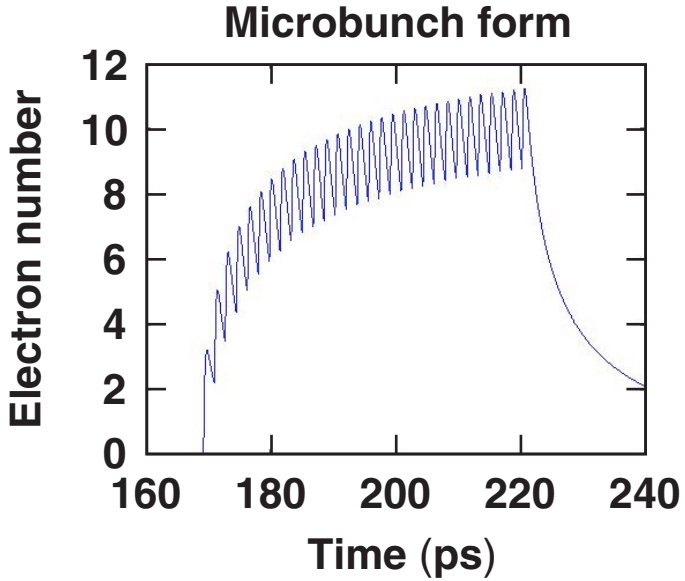
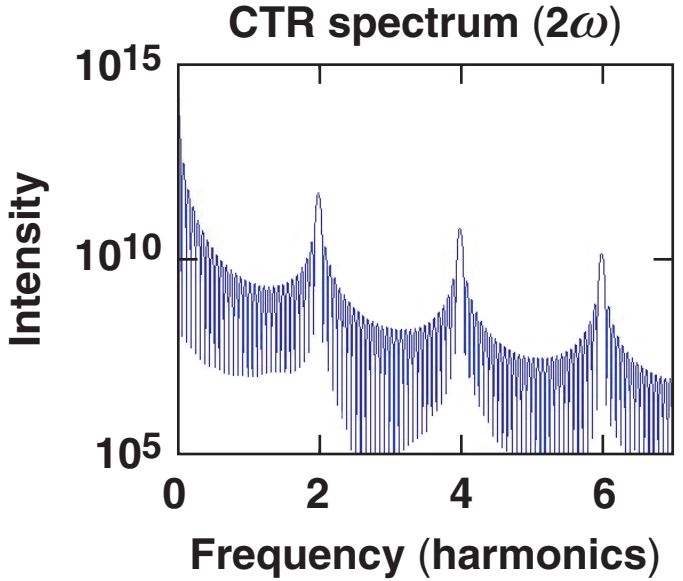
- Transition radiation (TR) is emitted when an electron crosses a refractive-index boundary.
- CTR arises from the coherent addition of the underlying TR fields.
- Structure written into the electron beam by the driver laser is the source of the coherence.





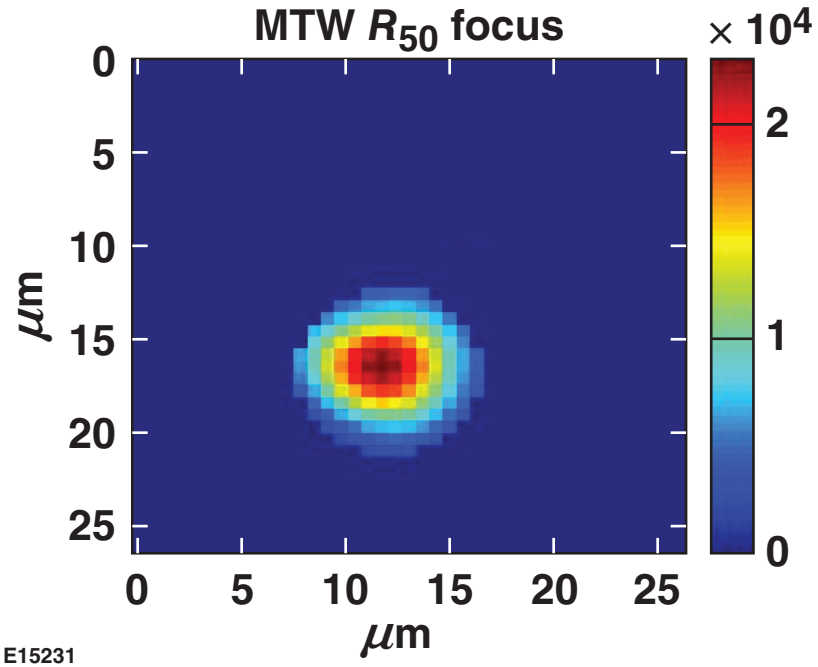
J. Zheng *et al.*, Phys. Plasmas 10, 2994 (2003).

The TRD is being developed using the MTW laser system

- The MTW laser is the front-end prototype for OMEGA EP.
- Its characteristics are broadly similar to other systems used in experiments where CTR diagnostics have been deployed.

$$\lambda = 1053\ \text{nm},\ \Delta t = 0.5\ \text{ps},\ E_{\text{max}} = 10\ \text{J}$$

- A 20-cm focal length off-axis parabola (OAP) focuses the beam.



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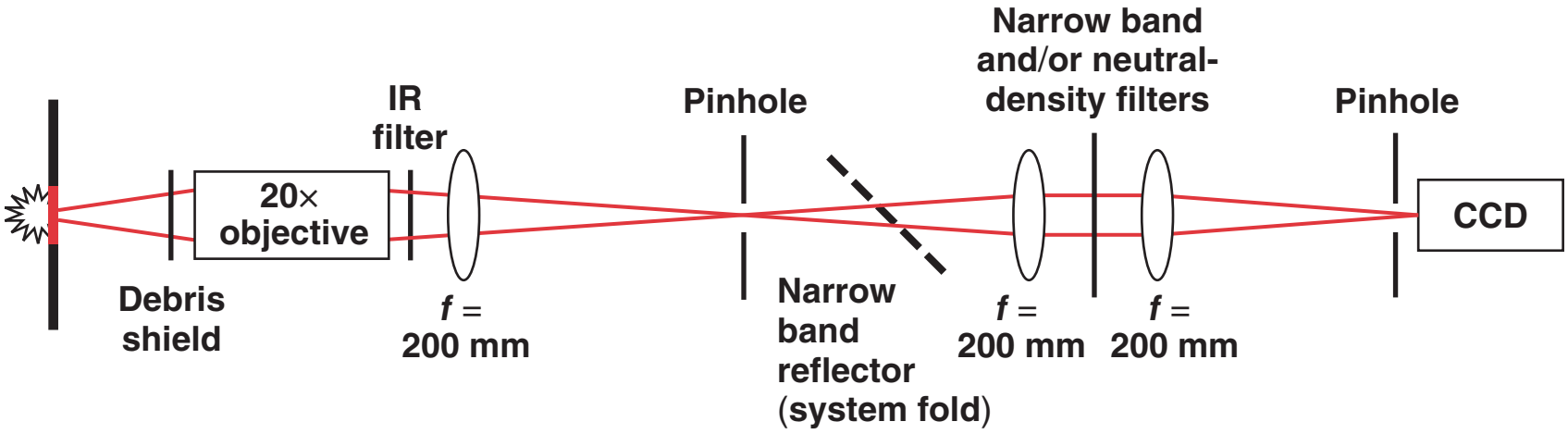
- The focal spot of the MTW seed laser is used to estimate the full energy on shot intensity.
- $R_{50} \approx 4\ \mu\text{m} \Rightarrow I_{50} \approx 2 \times 10^{19}\ \text{W/cm}^2$

The optical system is designed to provide high-resolution images of the rear surface emission

- A long working distance, infinity corrected, 20× objective provides the magnification.
- Filters and pinholes minimize the background.
- A Spectral Instruments 800 series CCD camera captures the images.



Field of view = 1.2 mm; Depth of focus = 1.6 μm

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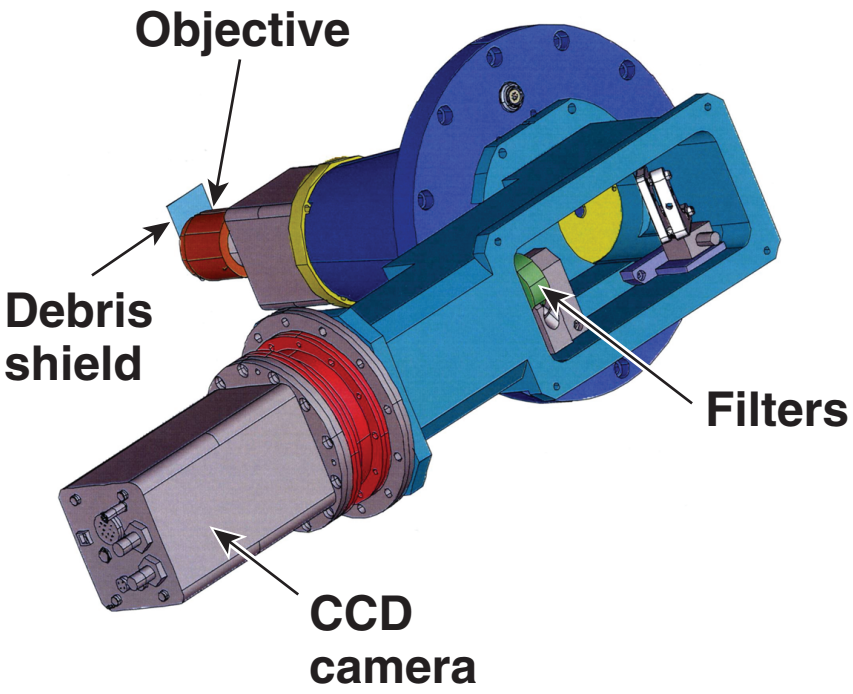
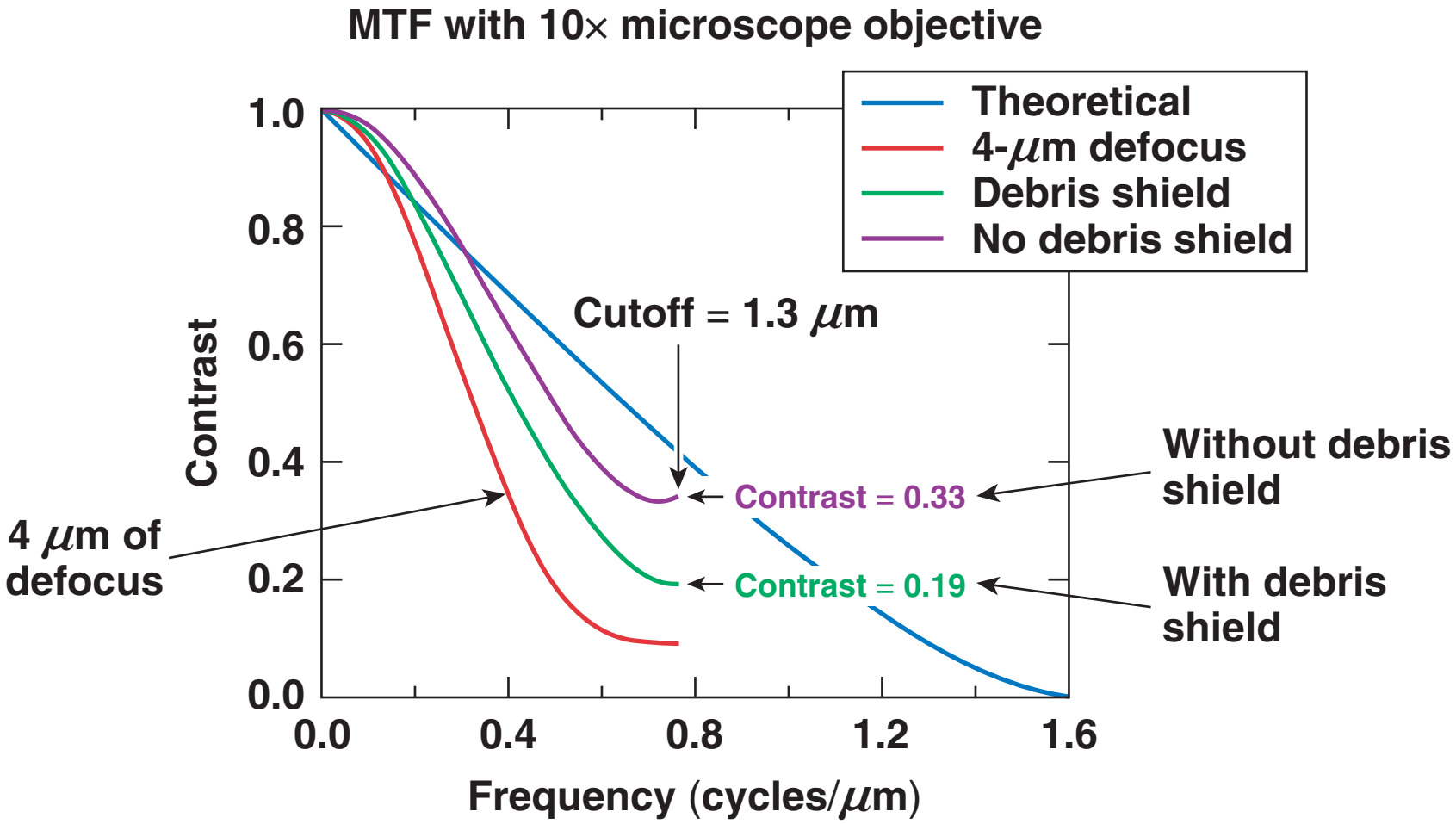
The mechanical design of the TRD is driven by shielding requirements



- The TRD occupies the port directly opposite the OAP.
- The optical axis is folded at 90° in order to shield the CCD detector with a lead wall.
- The objective can move with a 150-nm step size.
- A debris shield protects the objective from damage. This is replaced after each shot.

Modulation transfer function (MTF) analysis suggests the full system possesses submicron resolving power



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Calculations suggest a signal to background in excess of ten

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- At an intensity of 2×10^{19} W/cm^2 it is assumed that 30% of the laser energy is converted to fast electrons.
- For a 50-μm-thick target, the CTR signal should be of the order of 10^{-8} J to 10^{-7} J.
- Incoherent transition radiation and bremsstrahlung will contribute $\sim 10^{-12}$ J to the background.
- Blackbody radiation from the fast electron current should contribute another $\sim 10^{-11}$ J to the background.
- Emission due to shock breakout is likely to produce the largest background contribution $\sim 10^{-9}$ J.

J. Zheng *et al.*, Phys. Plasmas 10, 2994 (2003).

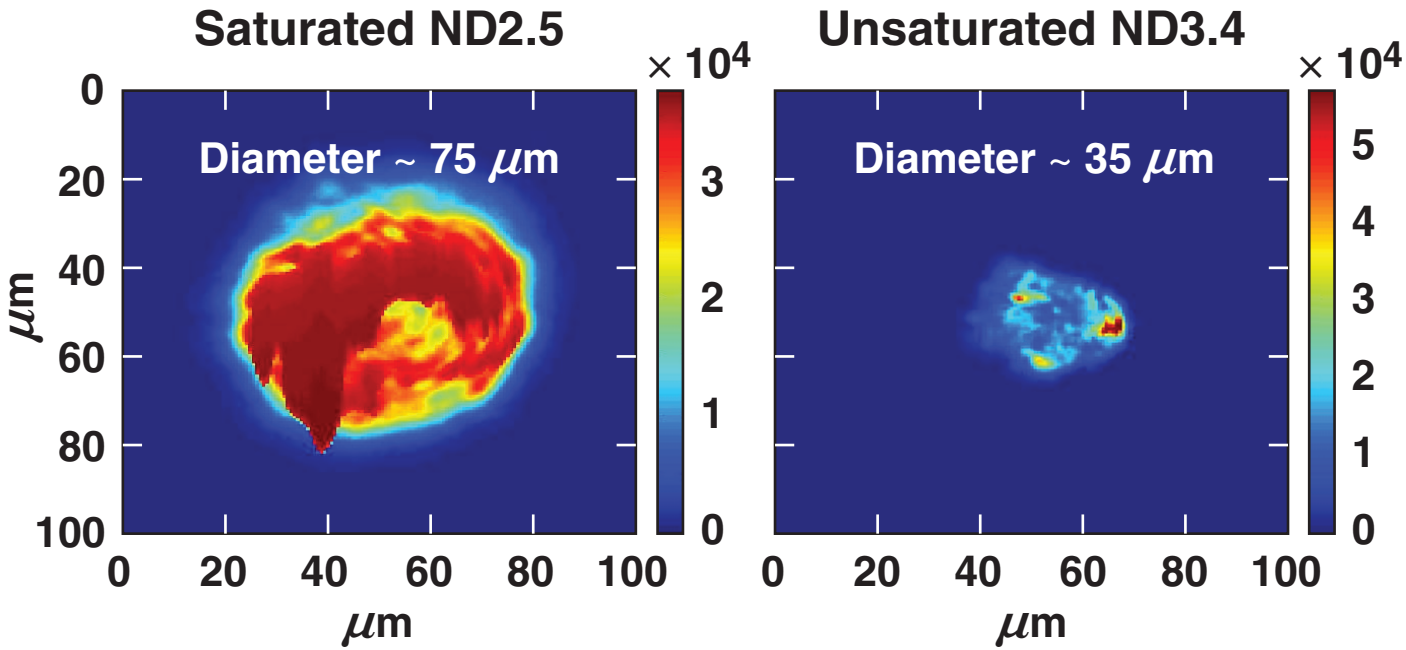
Strong signals at the second harmonic were obtained on the first shots

- Neutral-density (ND) filters are used to control the level of the detected signal.

12.5-μm Al foil

E_L = 3.2 J

Δt = 0.5 ps



Spectral window = 24 nm around 529 nm

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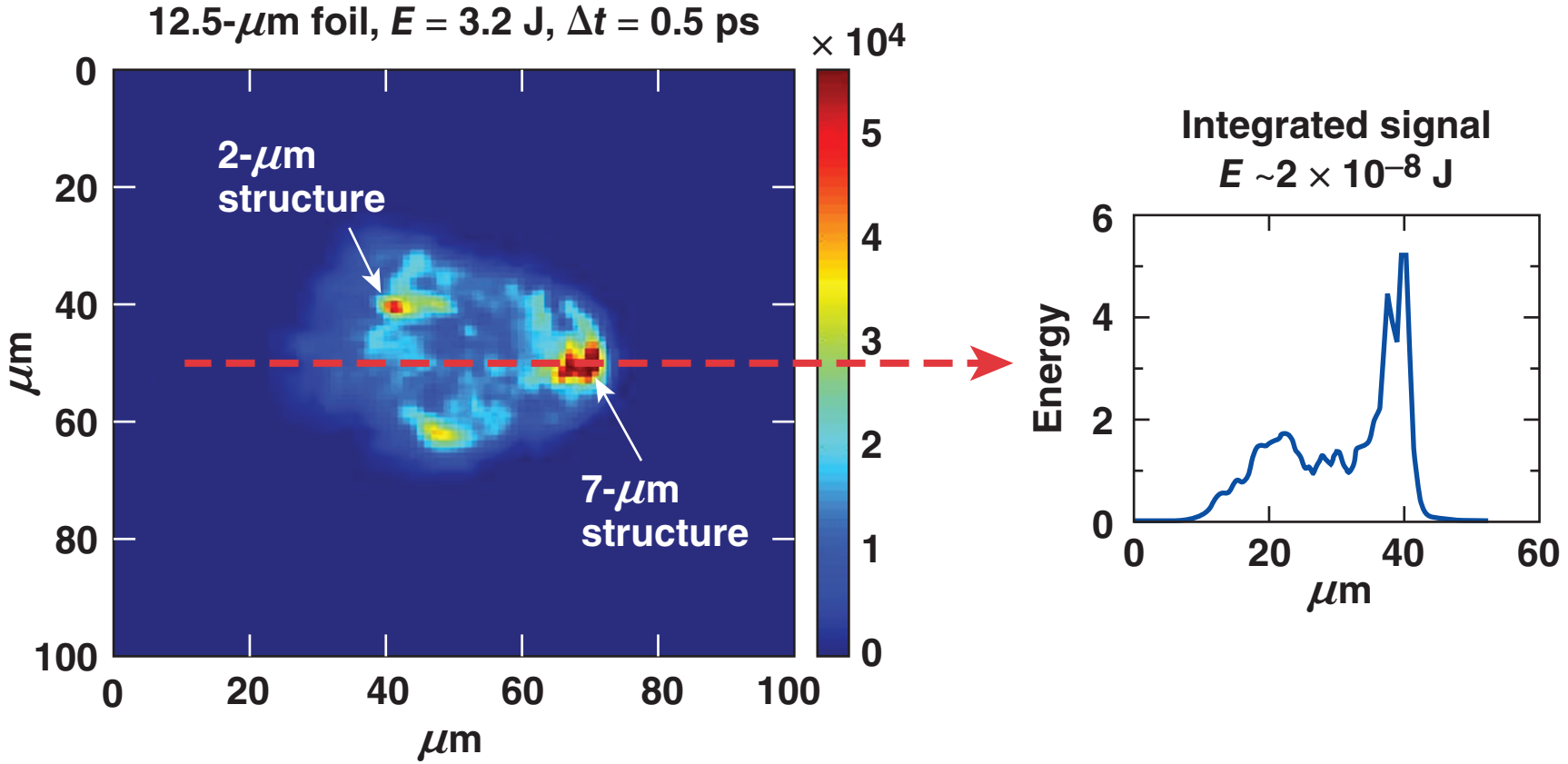
Structures with sizes as small as 2 μm are observed within the emission region



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Summary/Conclusions

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