

Microstructuring of bulk transparent solids using nanojoule femtosecond pulses

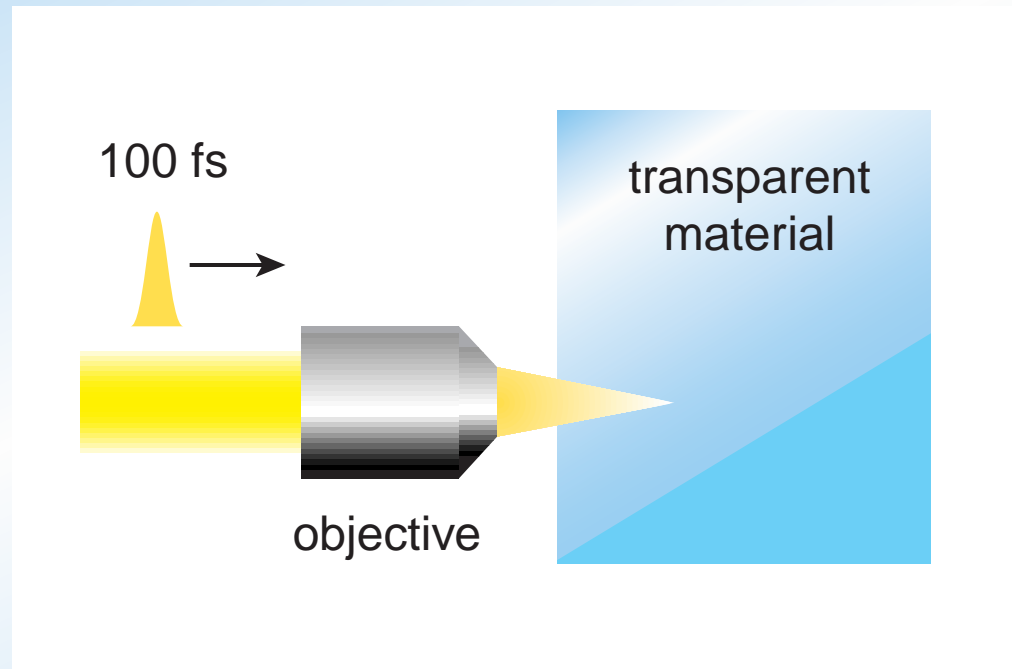
**Chris B. Schaffer
André Brodeur
Nozomi Nishimura
Eric Mazur**

**APS Centennial Meeting
23 March 1999**



Introduction

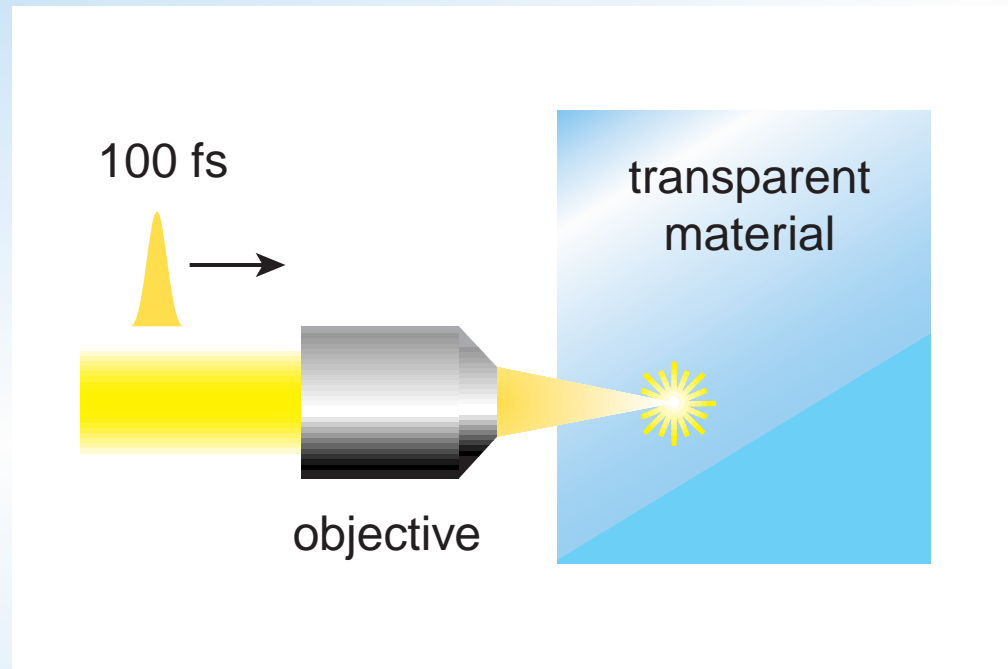
high intensity at focus...



Glezer, *et al.*, *Opt. Lett.* 21, 2023 (1996)

Introduction

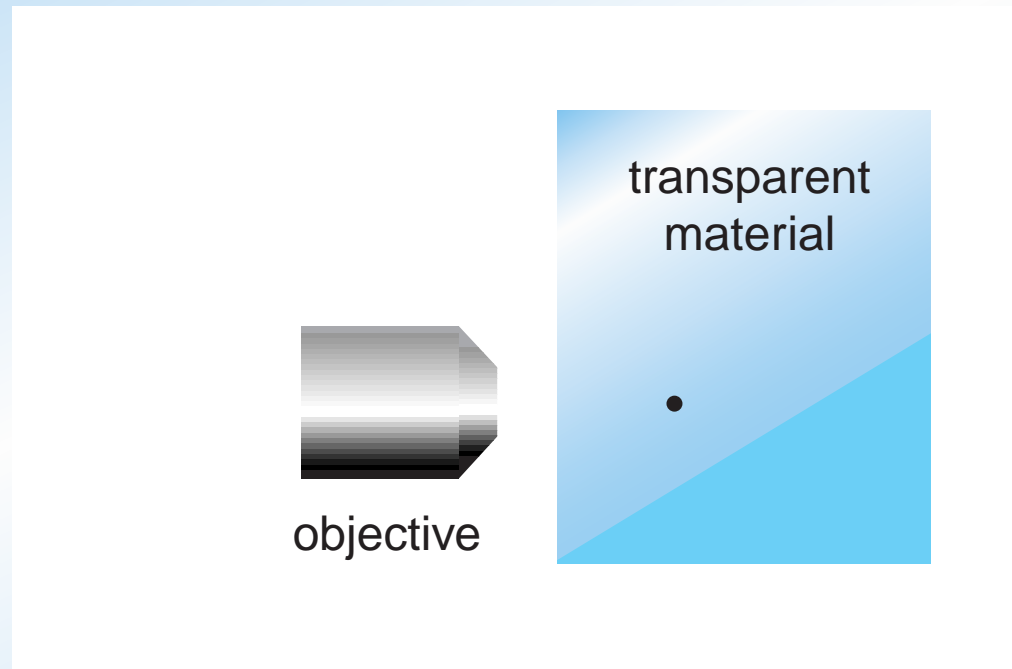
... causes nonlinear ionization...



Glezer, *et al.*, *Opt. Lett.* 21, 2023 (1996)

Introduction

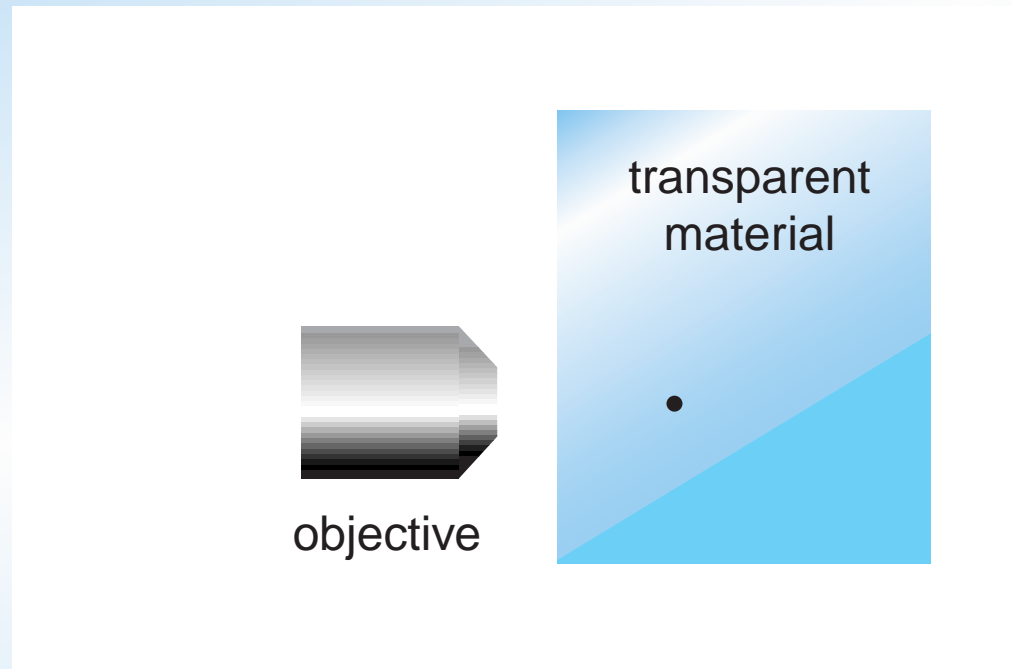
and microscopic bulk damage



Glezer, et al., Opt. Lett. 21, 2023 (1996)

Introduction

and microscopic bulk damage

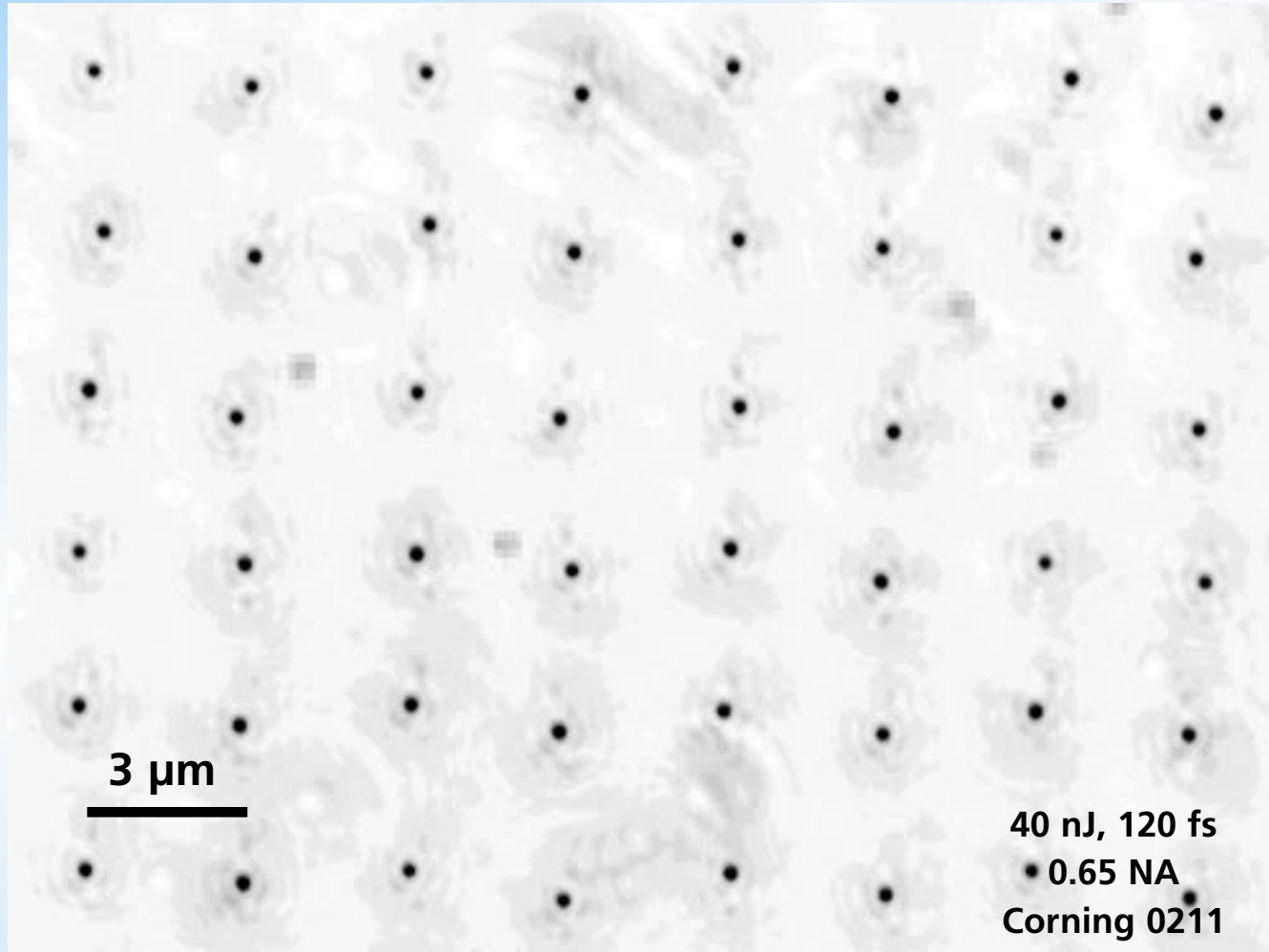


with only tens of nanojoules!

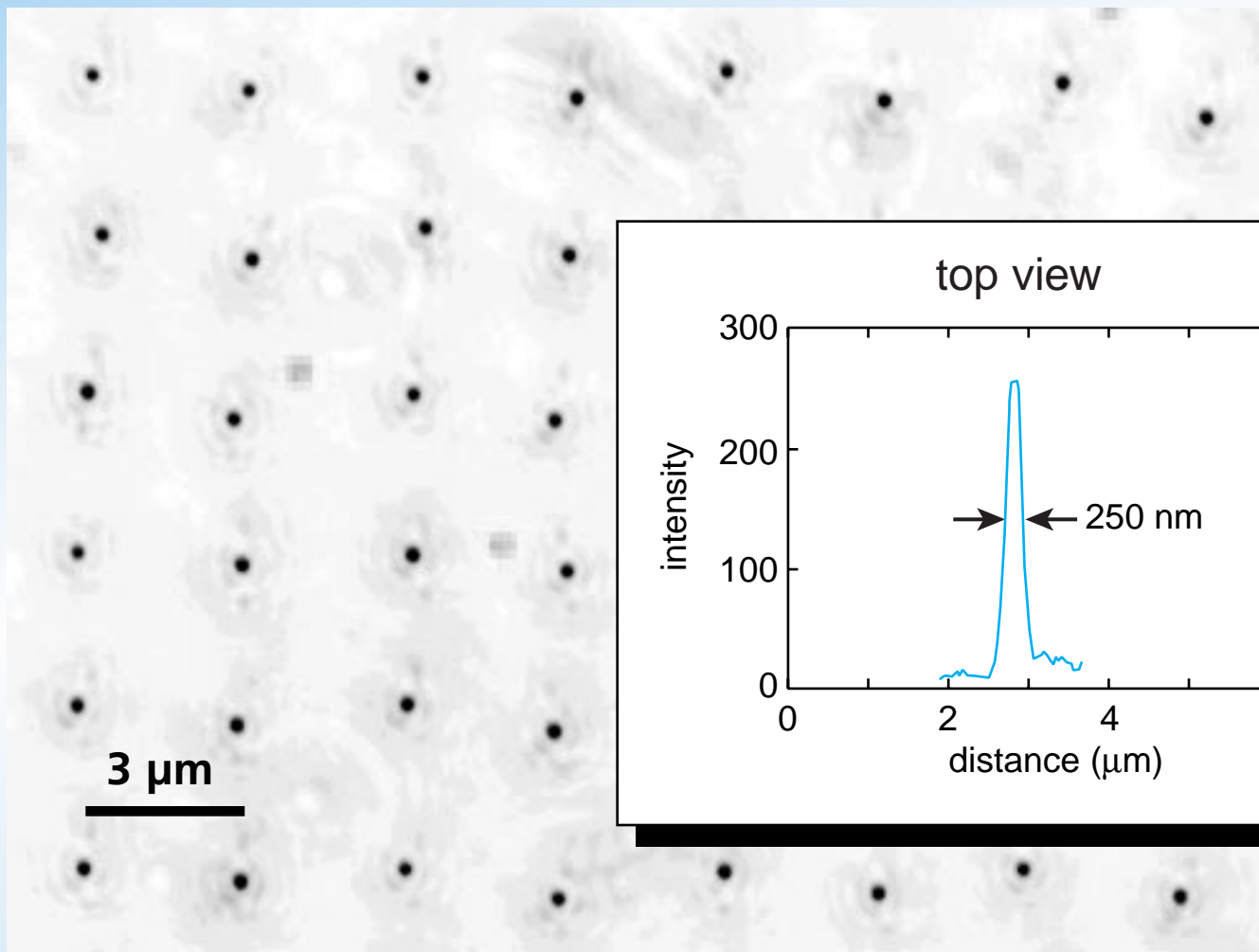
Outline

- ▶ **Damage morphology**
- ▶ **Thresholds**
- ▶ **Ionization mechanisms**

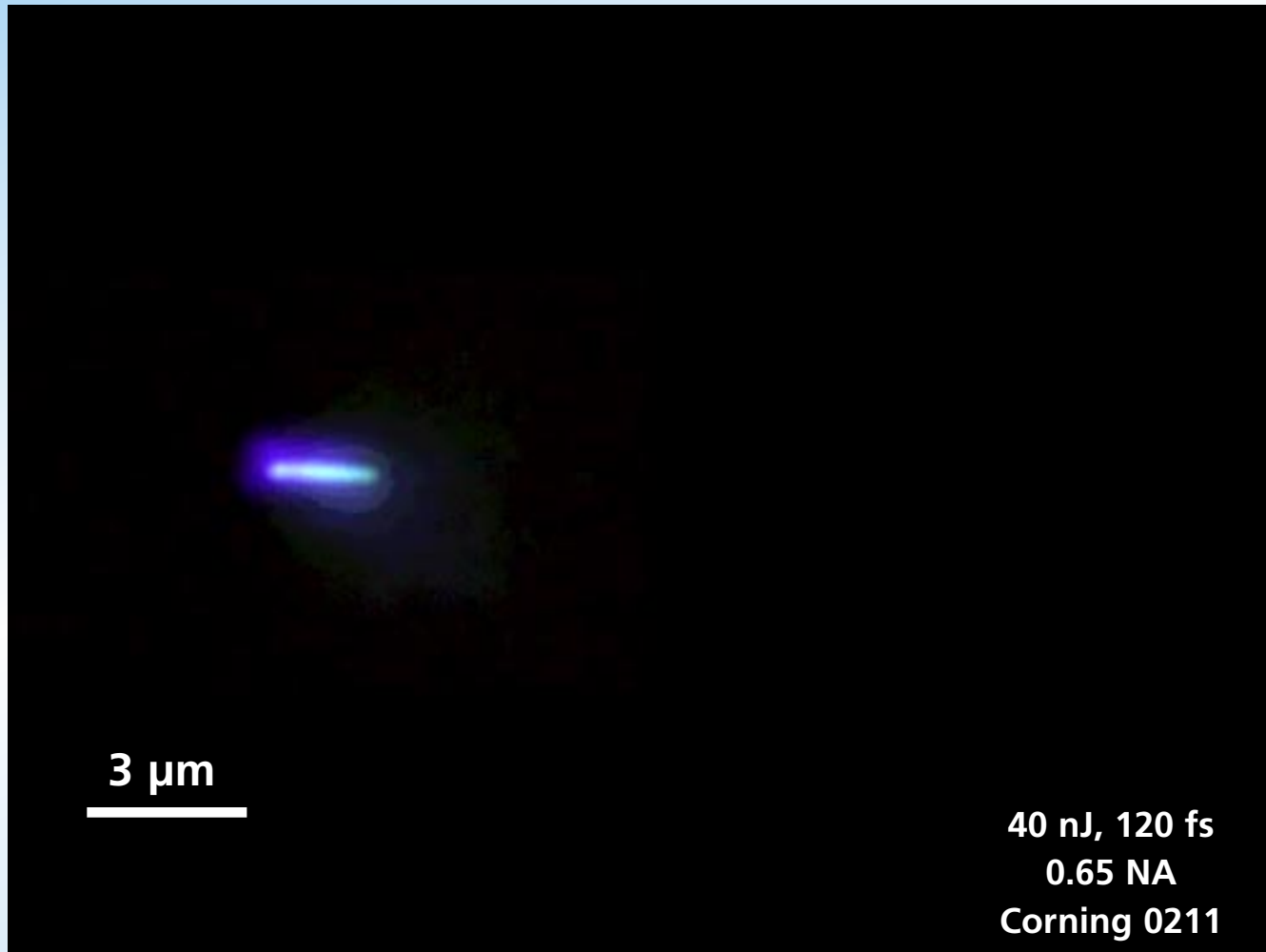
Damage morphology



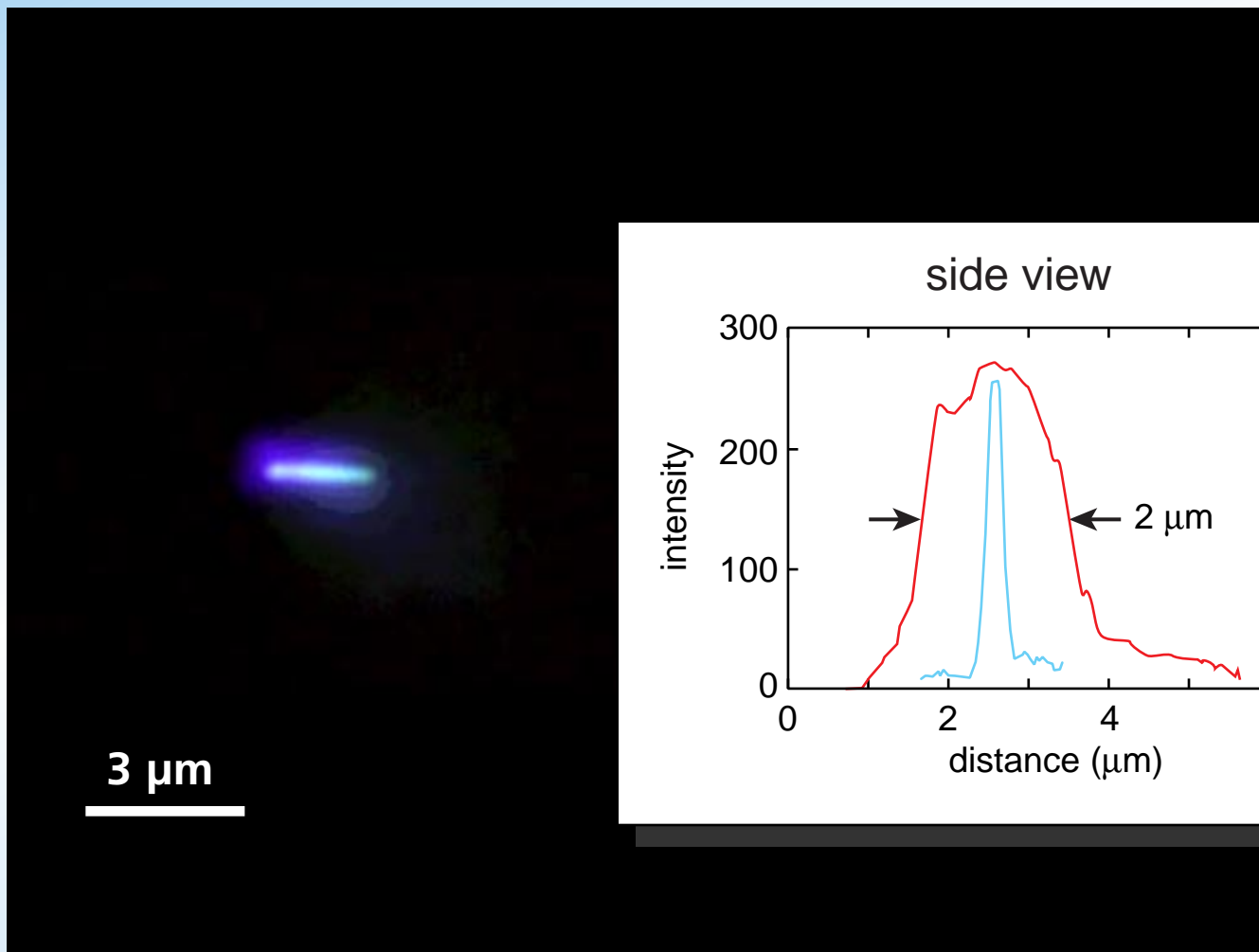
Damage morphology



Damage morphology



Damage morphology



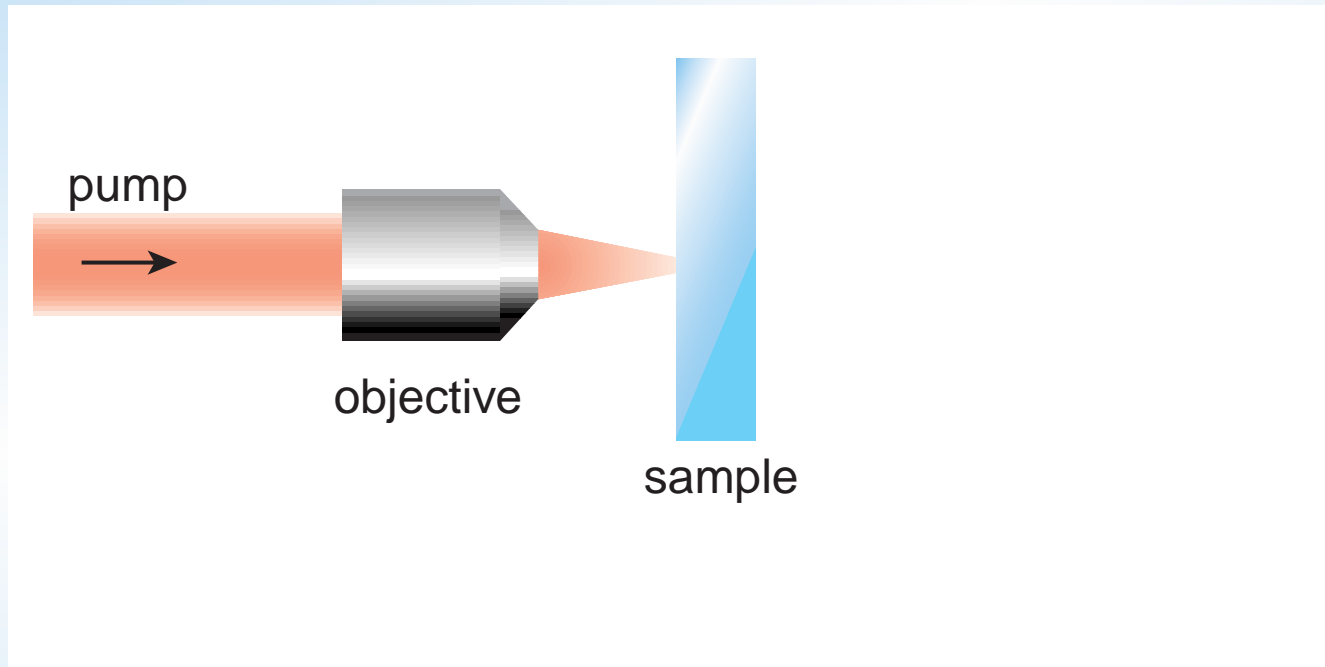
Thresholds

how little energy produces permanent changes?



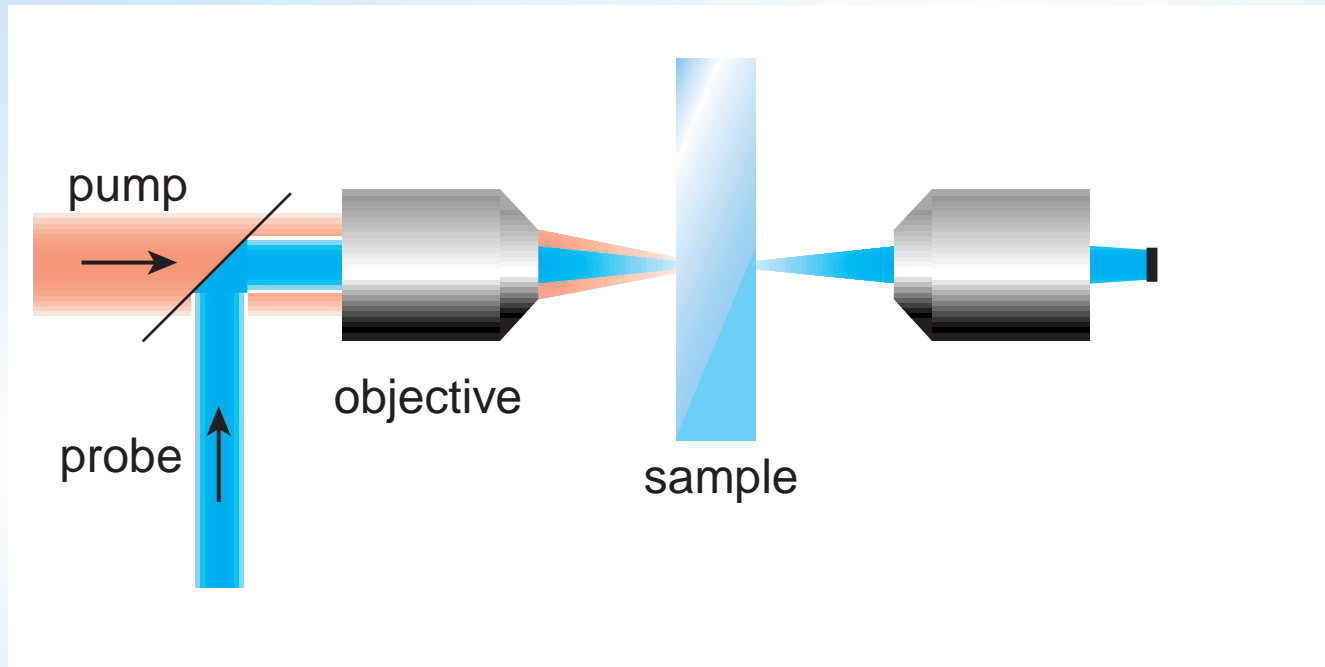
Thresholds

Bring in pump beam...



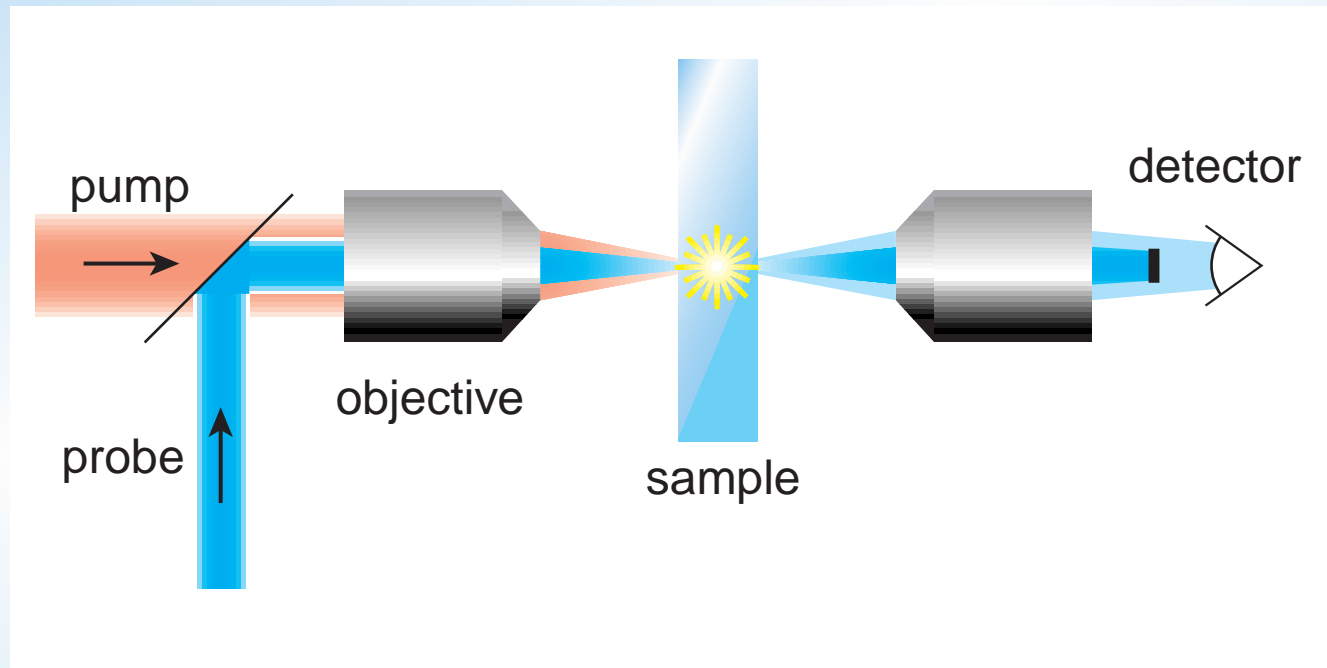
Thresholds

... block probe beam...



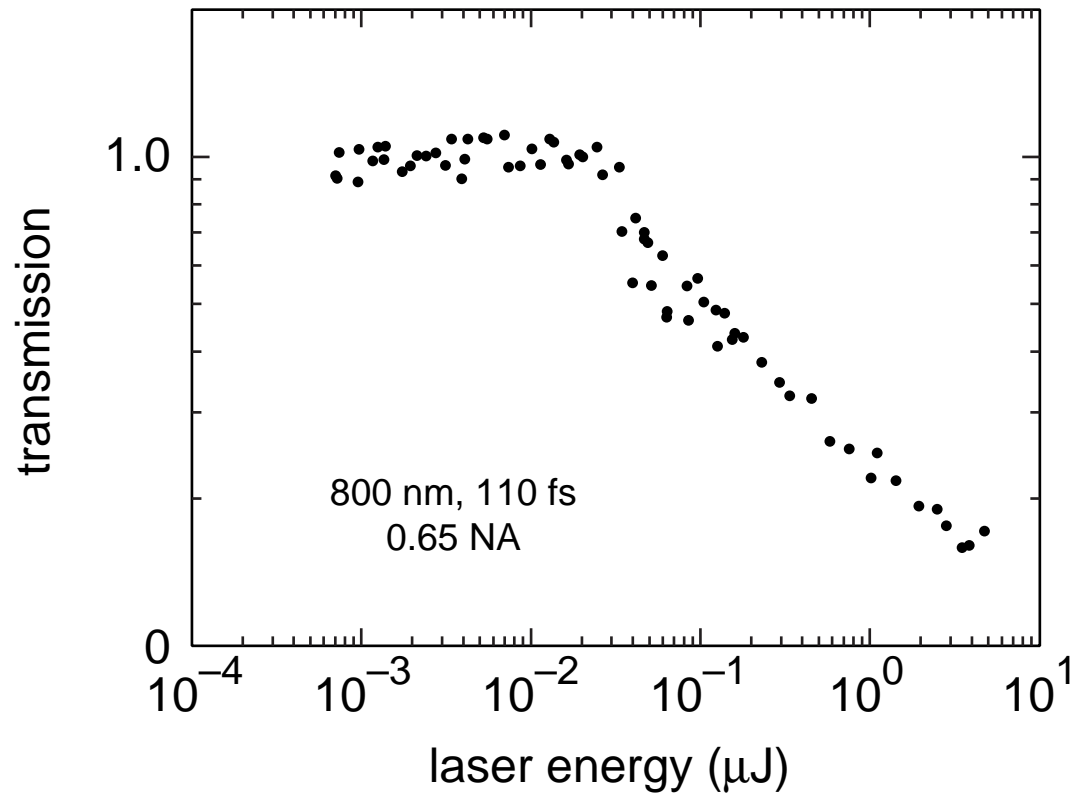
Thresholds

... and detect light scattered by damage



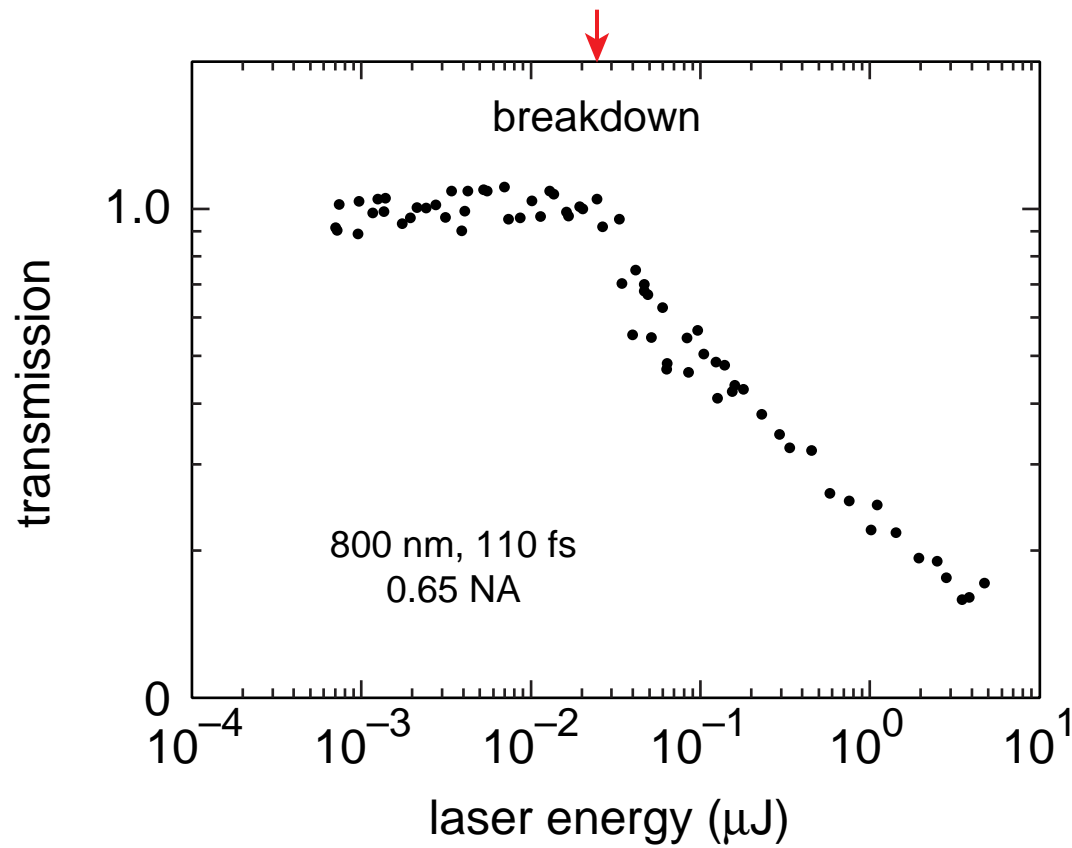
Thresholds

transmission of pump beam in fused silica



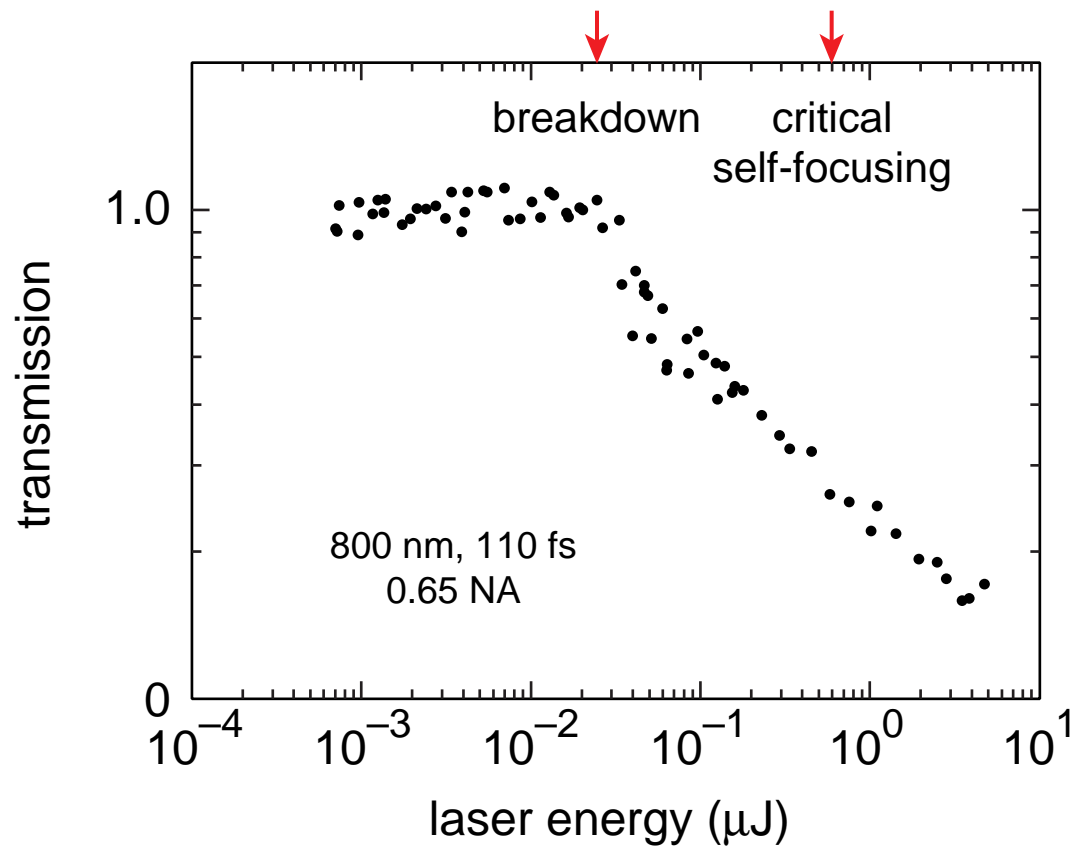
Thresholds

transmission of pump beam in fused silica



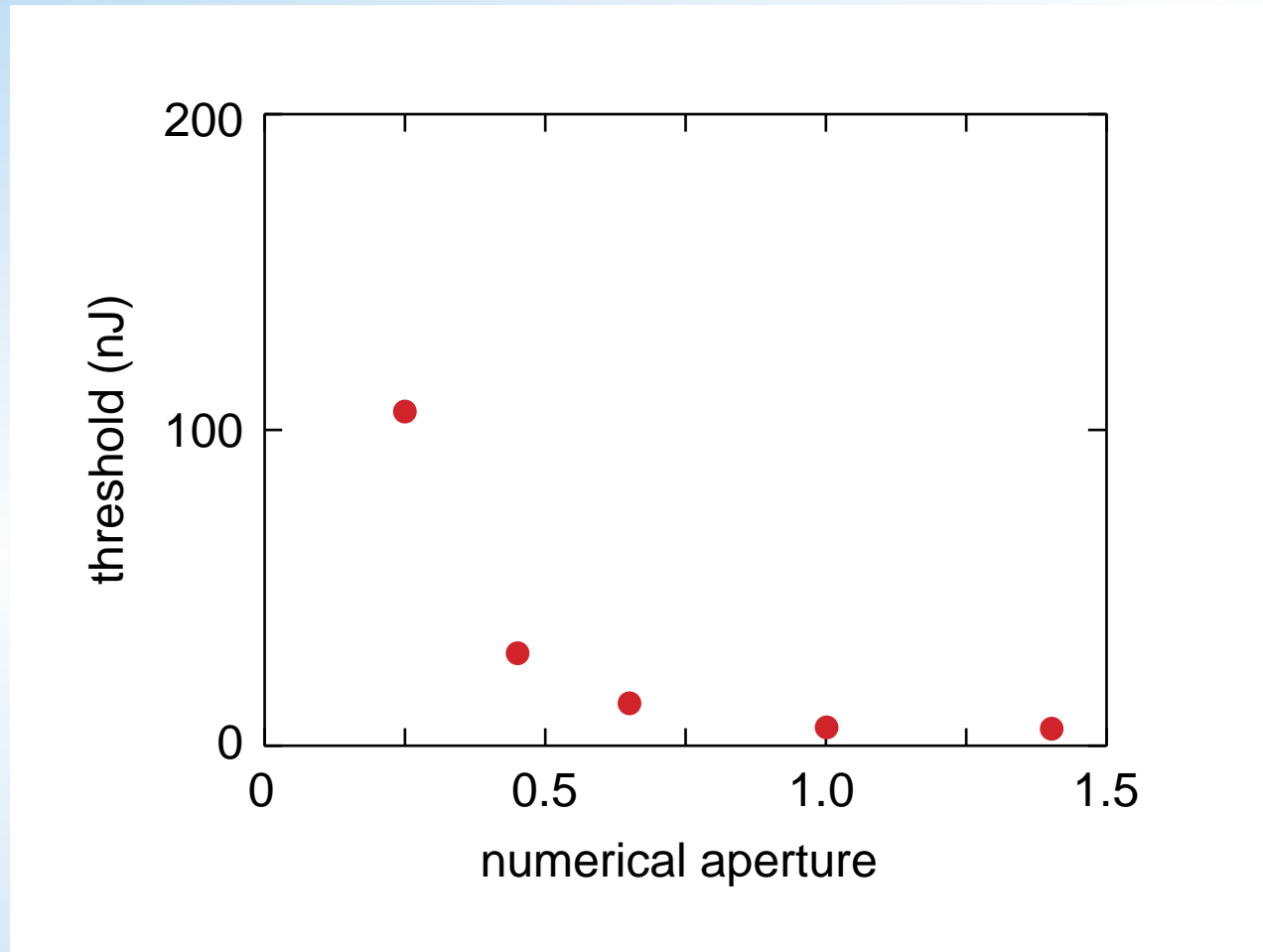
Thresholds

transmission of pump beam in fused silica



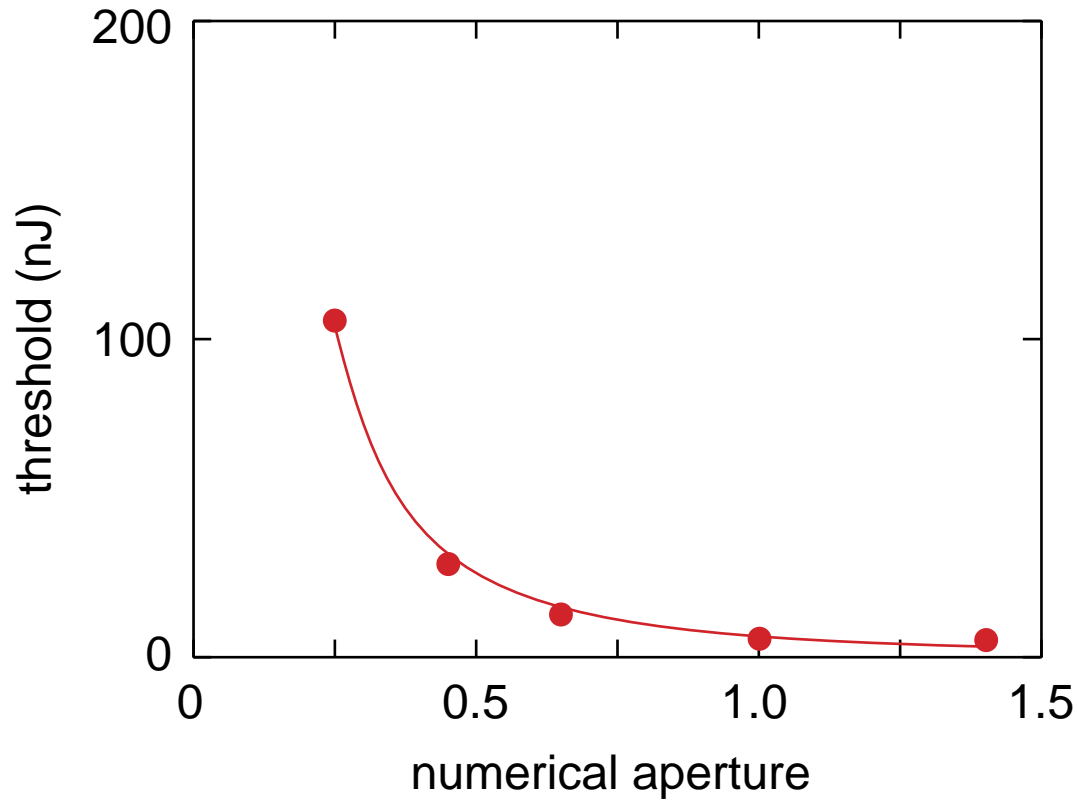
Thresholds

vary numerical aperture in Corning 0211



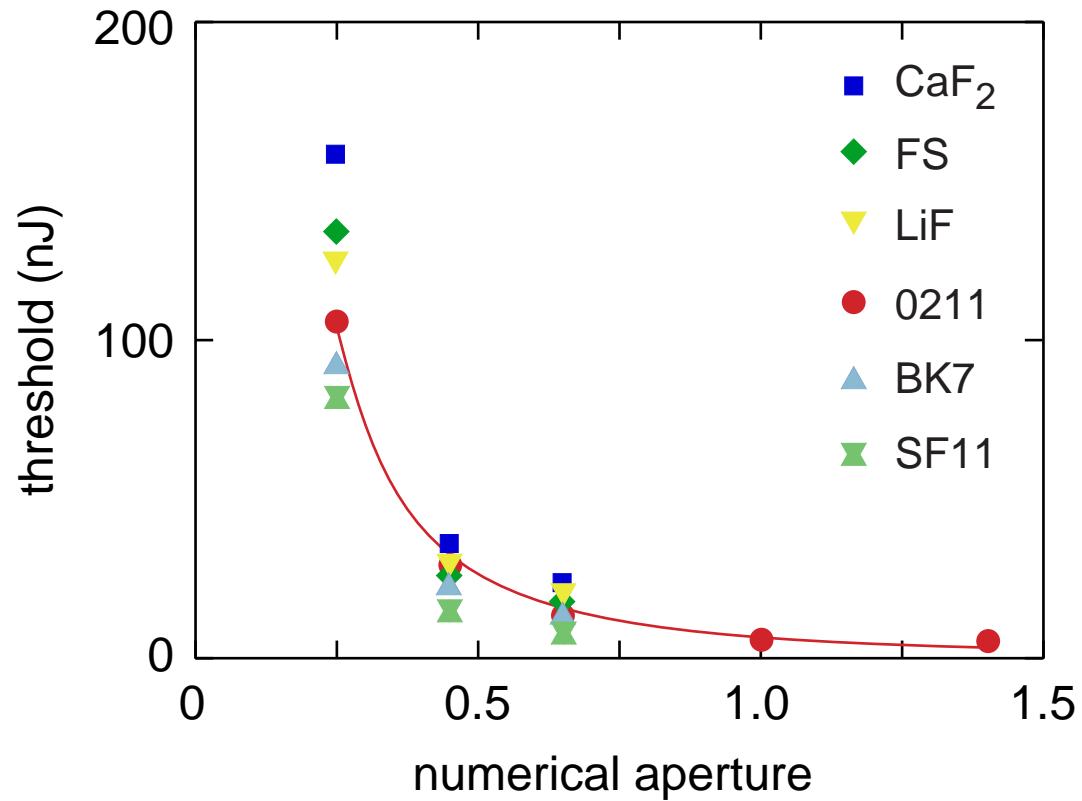
Thresholds

fit gives threshold intensity: $I_0 = 2.7 \times 10^{17} \text{ W/m}^2$



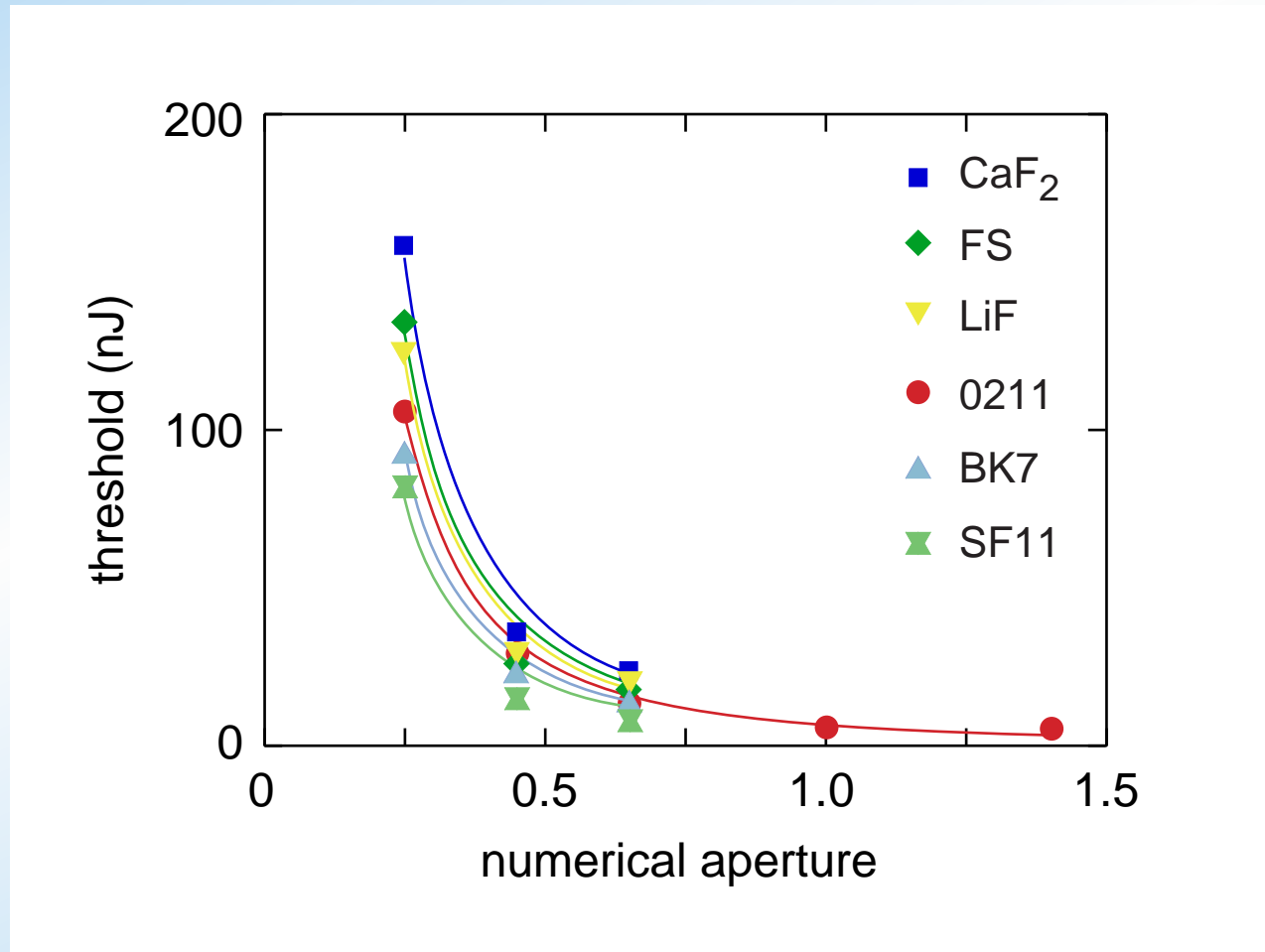
Thresholds

other materials...



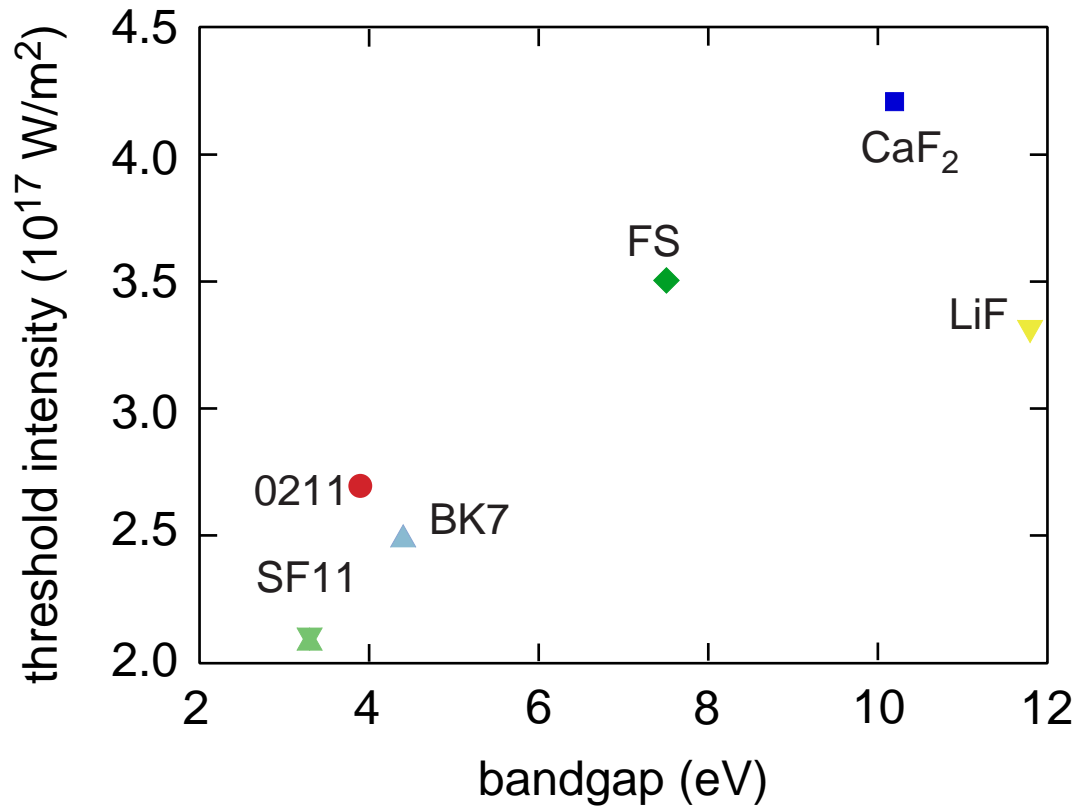
Thresholds

... give other thresholds



Thresholds

threshold increases with bandgap



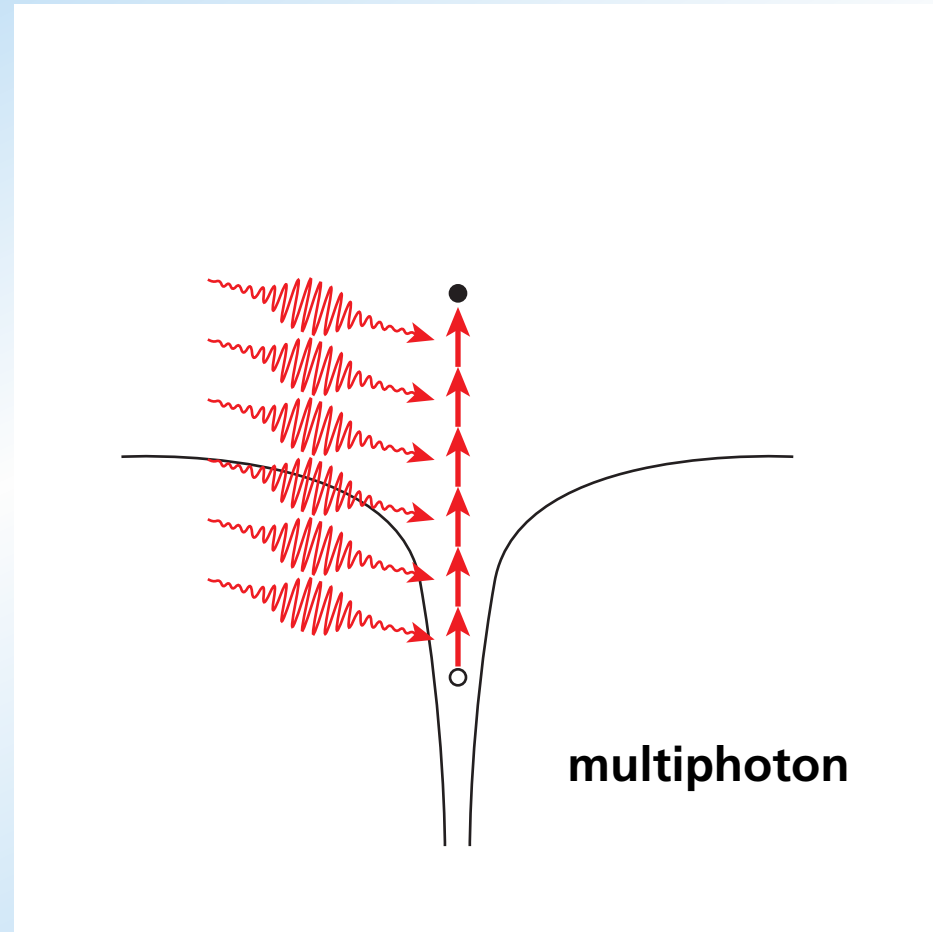
Mechanisms

what do thresholds tell about ionization?

A faint, circular, textured pattern resembling a ripple or a diffraction pattern, centered on a dark spot. The pattern consists of concentric, slightly irregular rings with a grainy, mottled appearance, set against a light gray background. The central dark spot is a small, solid black circle.

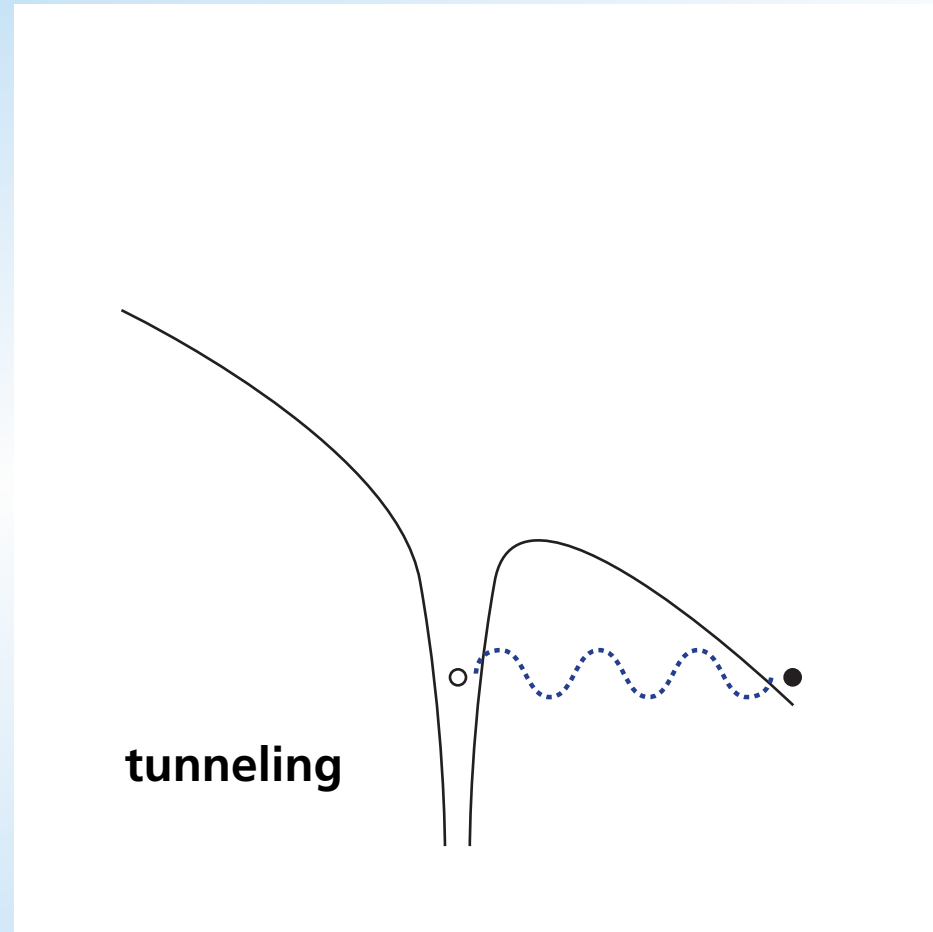
Mechanisms

laser field ionization



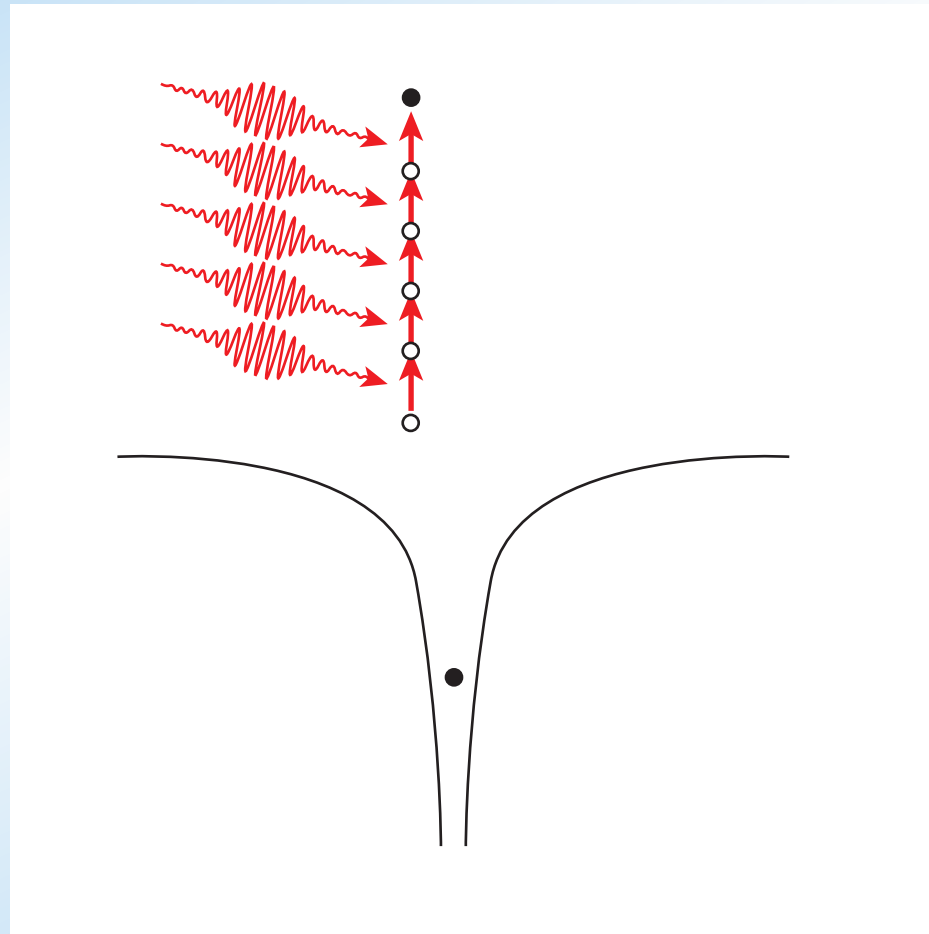
Mechanisms

laser field ionization



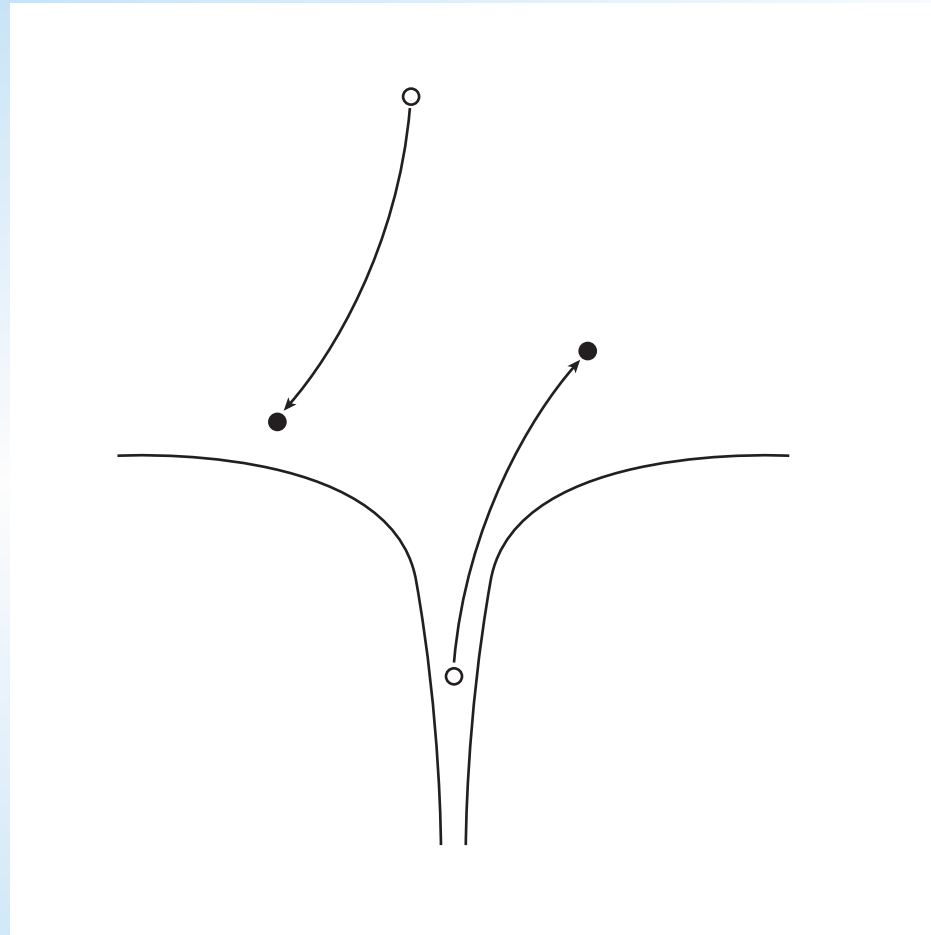
Mechanisms

impact ionization



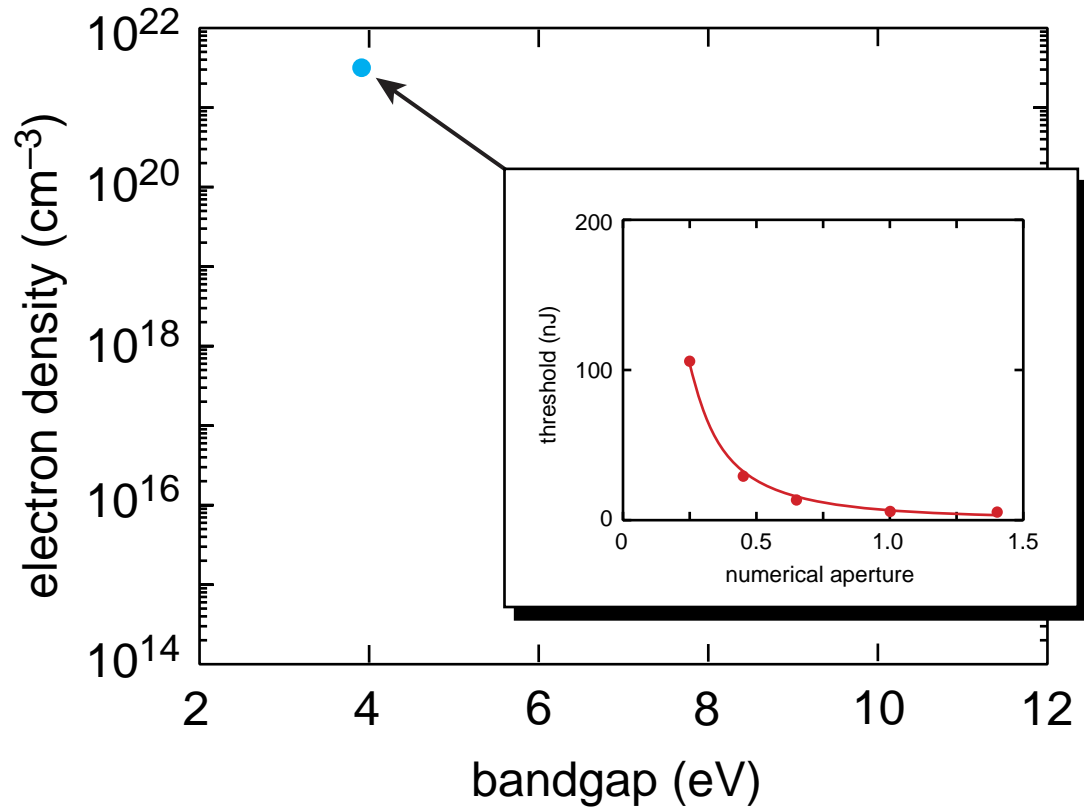
Mechanisms

impact ionization



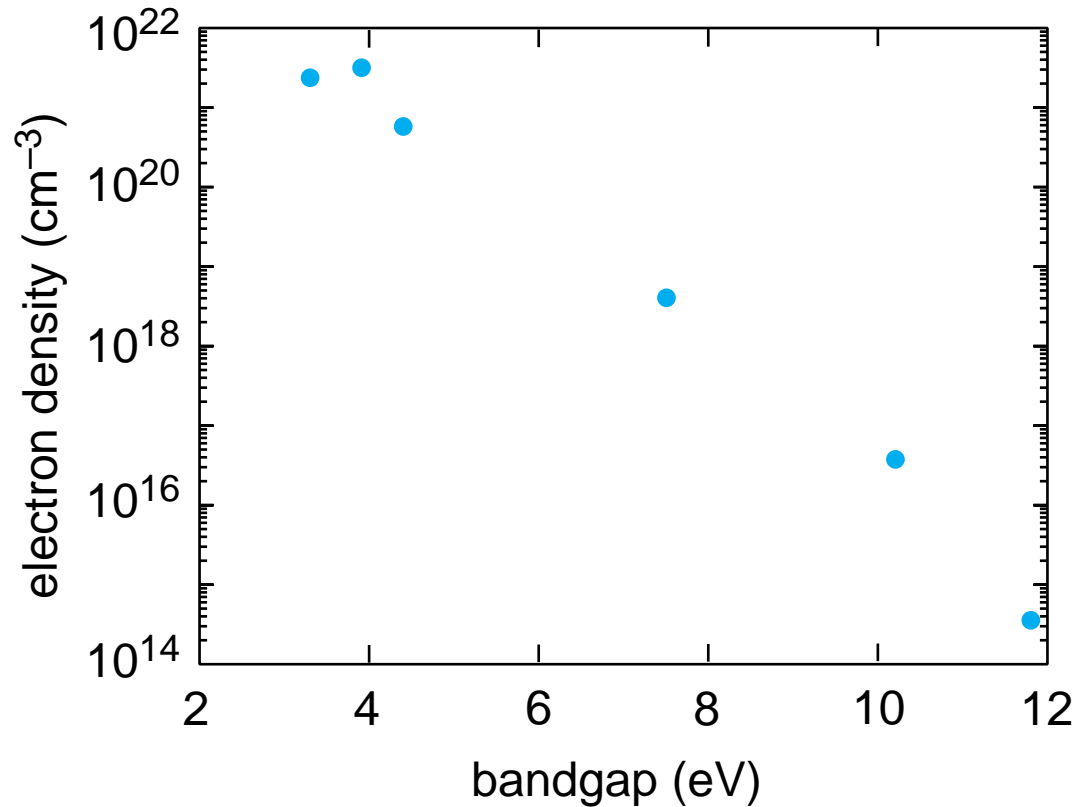
Mechanisms

threshold gives field ionization electron density



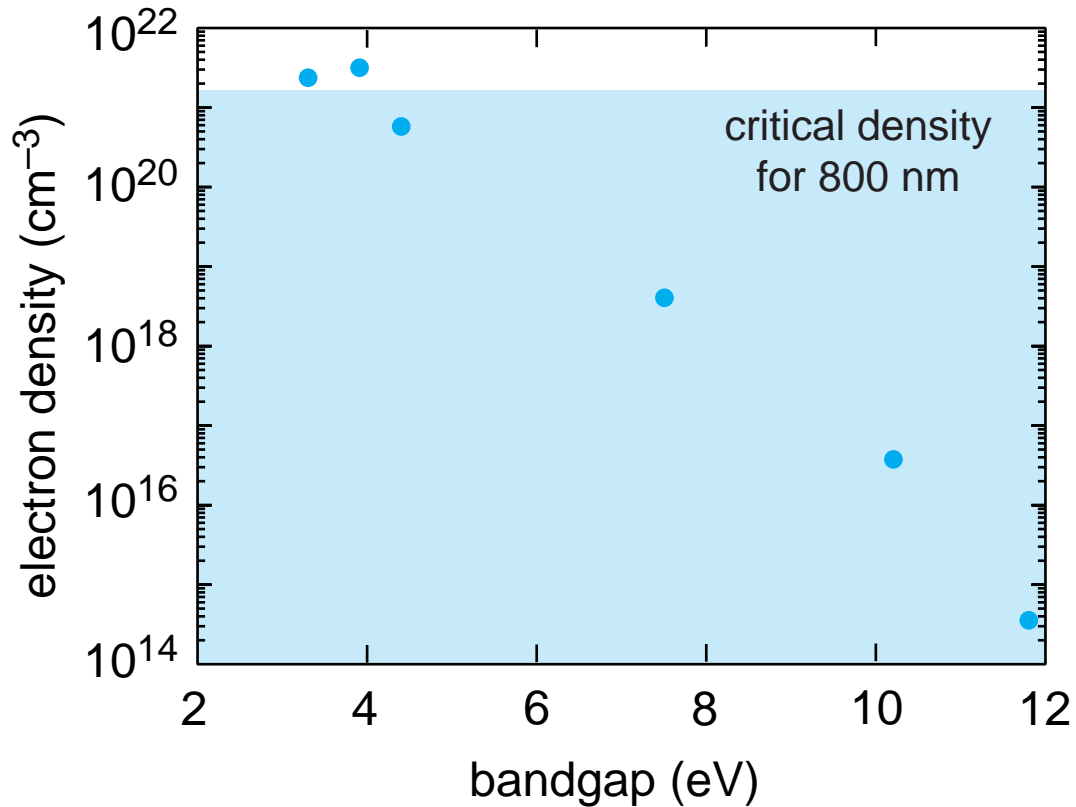
Mechanisms

threshold gives field ionization electron density



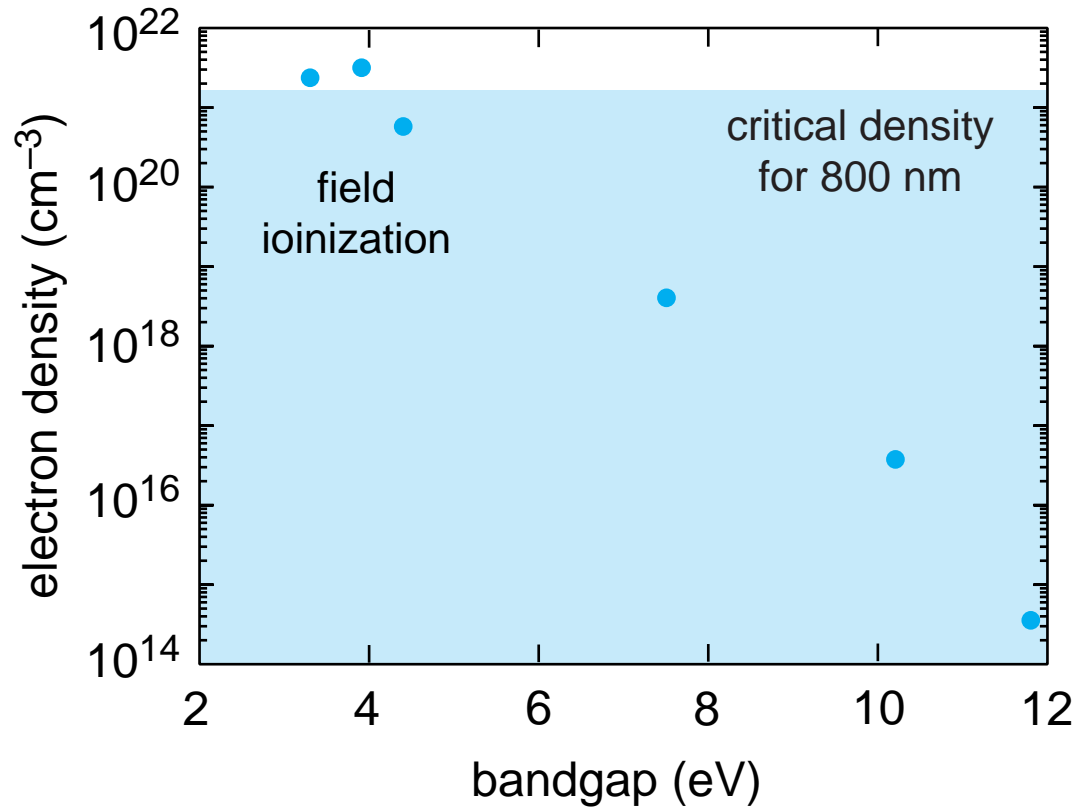
Mechanisms

need critical electron density to damage



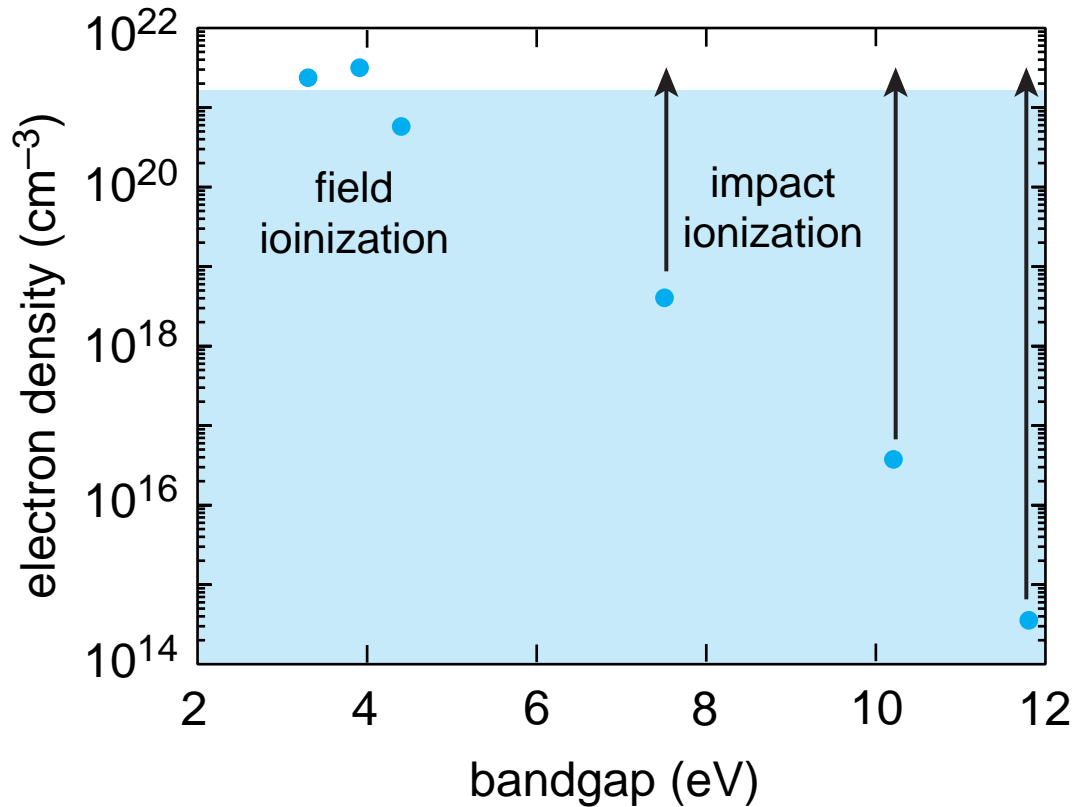
Mechanisms

for low bandgap field ionization is sufficient



Mechanisms

for high gap impact ionization required



Summary

- ▶ **damage with only nanojoules**
- ▶ **microstructuring without amplifiers**
- ▶ **transition from field to impact ionization**

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**For a copy of this talk and
additional information, see:**

<http://mazur-www.harvard.edu>