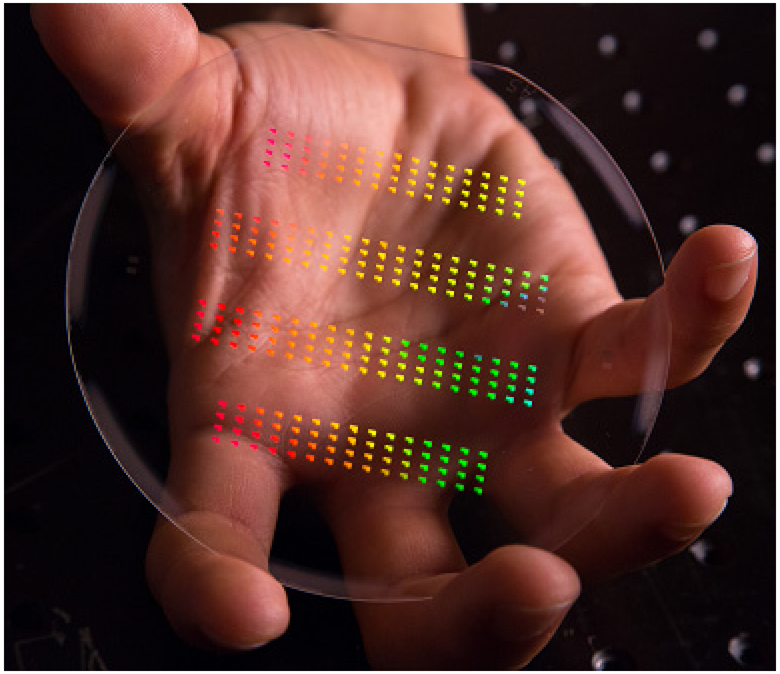
Acceleration of electrons in a laser-driven dielectric microstructure



Edgar A. Peralta
Stanford University

NA-PAC '13
Pasadena, CA
Sept 30th, 2013

SLAC NATIONAL ACCELERATOR LABORATORY

Results recently published

nature International weekly journal of science

NATURE | LETTER near-final version

Demonstration of electron acceleration in a laser-driven dielectric microstructure

E. A. Peralta, K. Soong, R. J. England, E. R. Colby, Z. Wu, B. Montazeri, C. McGuinness, J. McNeur, K. J. Leedle, D. Walz, E. B. Sozer, B. Cowan, B. Schwartz, G. Travish & R. L. Byer

Affiliations | Contributions | Corresponding author

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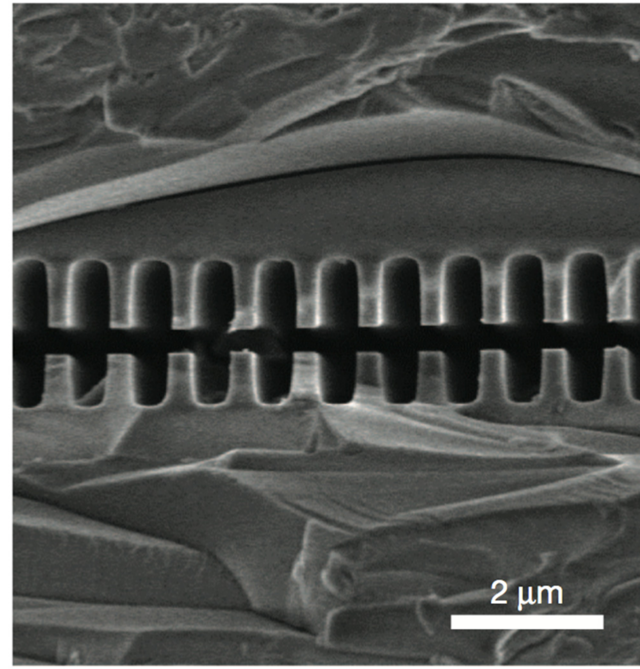
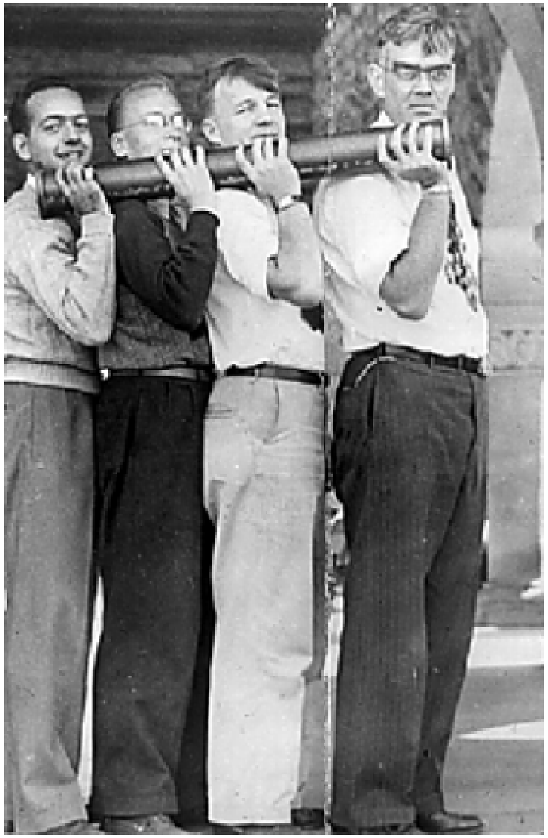


"Here we report high-gradient (beyond 250 MeV m^{-1}) acceleration of electrons in a DLA. Relativistic (60-MeV) electrons are energy-modulated over 563 ± 104 optical periods of a fused silica grating structure, powered by a 800-nm-wavelength mode-locked Ti:sapphire laser."

A promising technology: DLA

Mark I LINAC
(Metals, RF fields)



1 m long (1947)
2 MeV/m gradient

Grating DLA
(Dielectrics, laser fields)

.001 m long (2013)
300 MeV/m gradient

Proof of principle structure

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **9**, 111301 (2006)

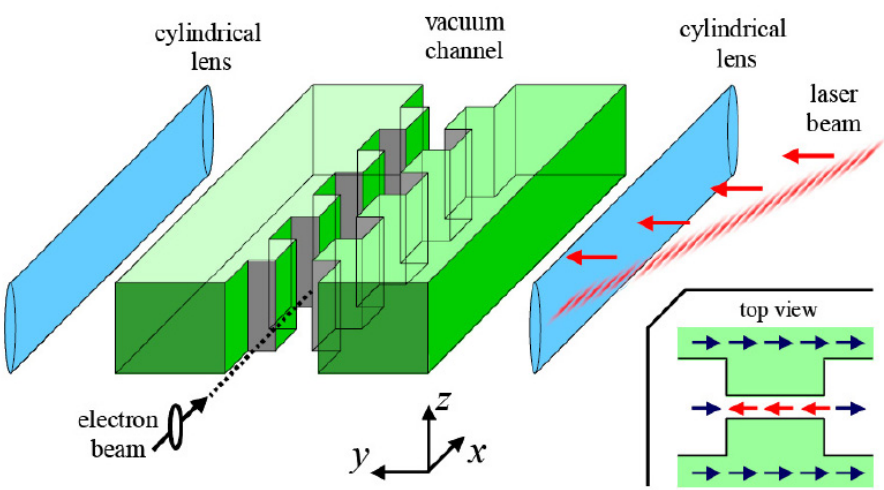
Proposed few-optical cycle laser-driven particle accelerator structure

T. Plettner, P. P. Lu, and R. L. Byer

E.L. Ginzton Laboratories, Stanford University, Stanford, California 94305, USA

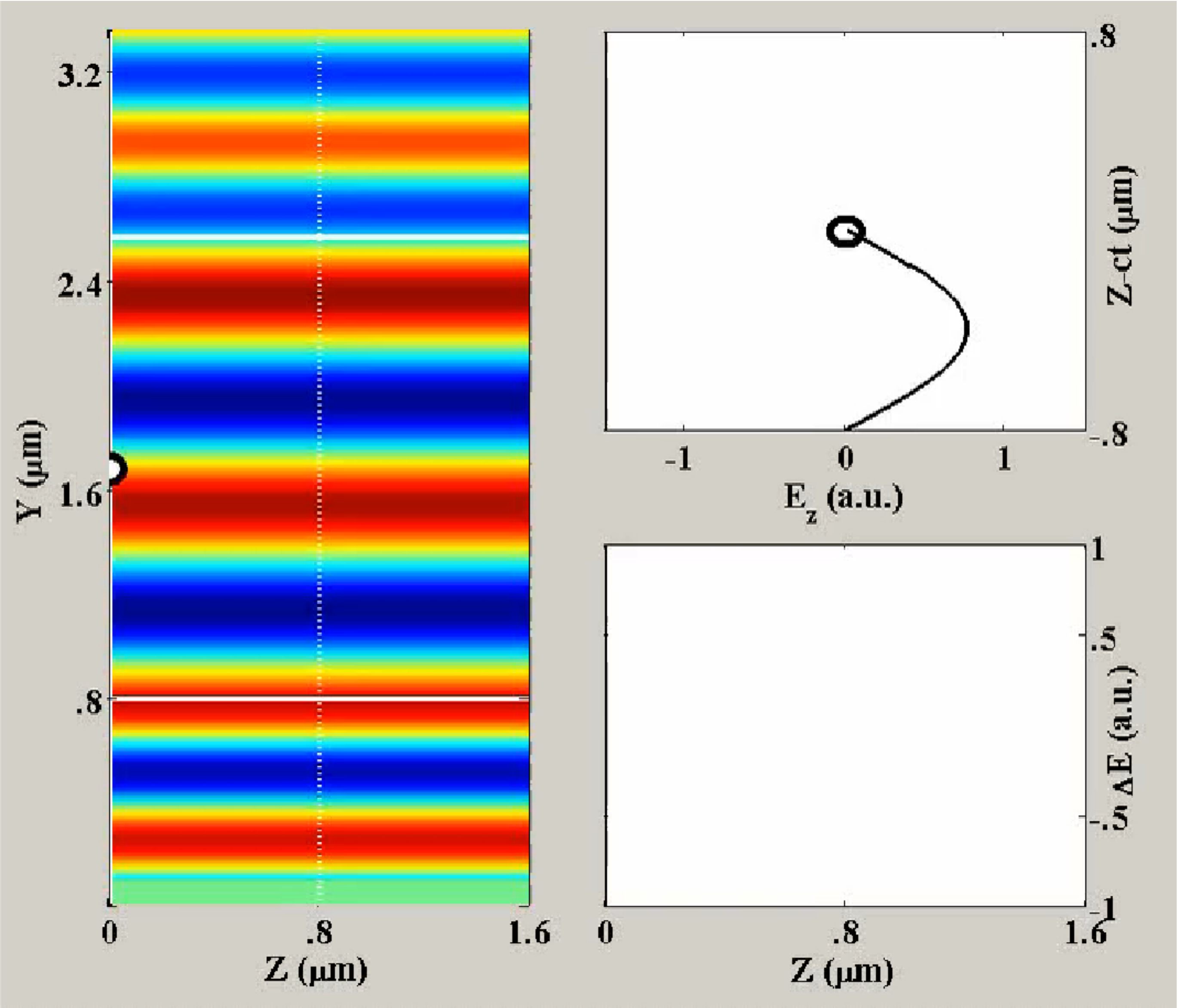
(Received 2 October 2006; published 14 November 2006)

We describe a transparent dielectric grating accelerator structure that is designed for ultrashort laser pulse operation. The structure is based on the principle of periodic field reversal to achieve phase

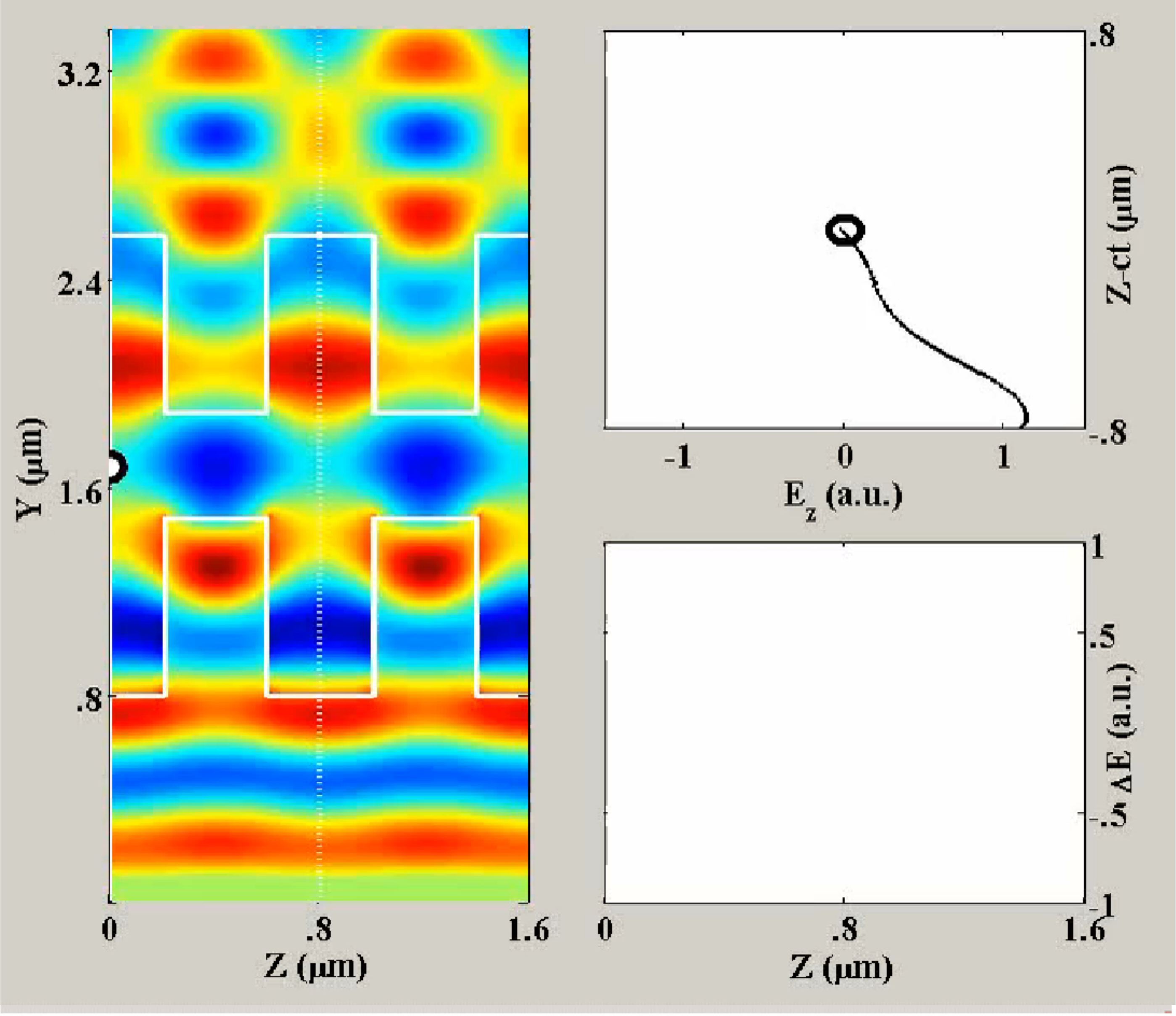


- Minimal material dispersion
- Field incident normal to beam path
- Slab geometry ideal for heat removal
- Capable of GeV/m gradients!

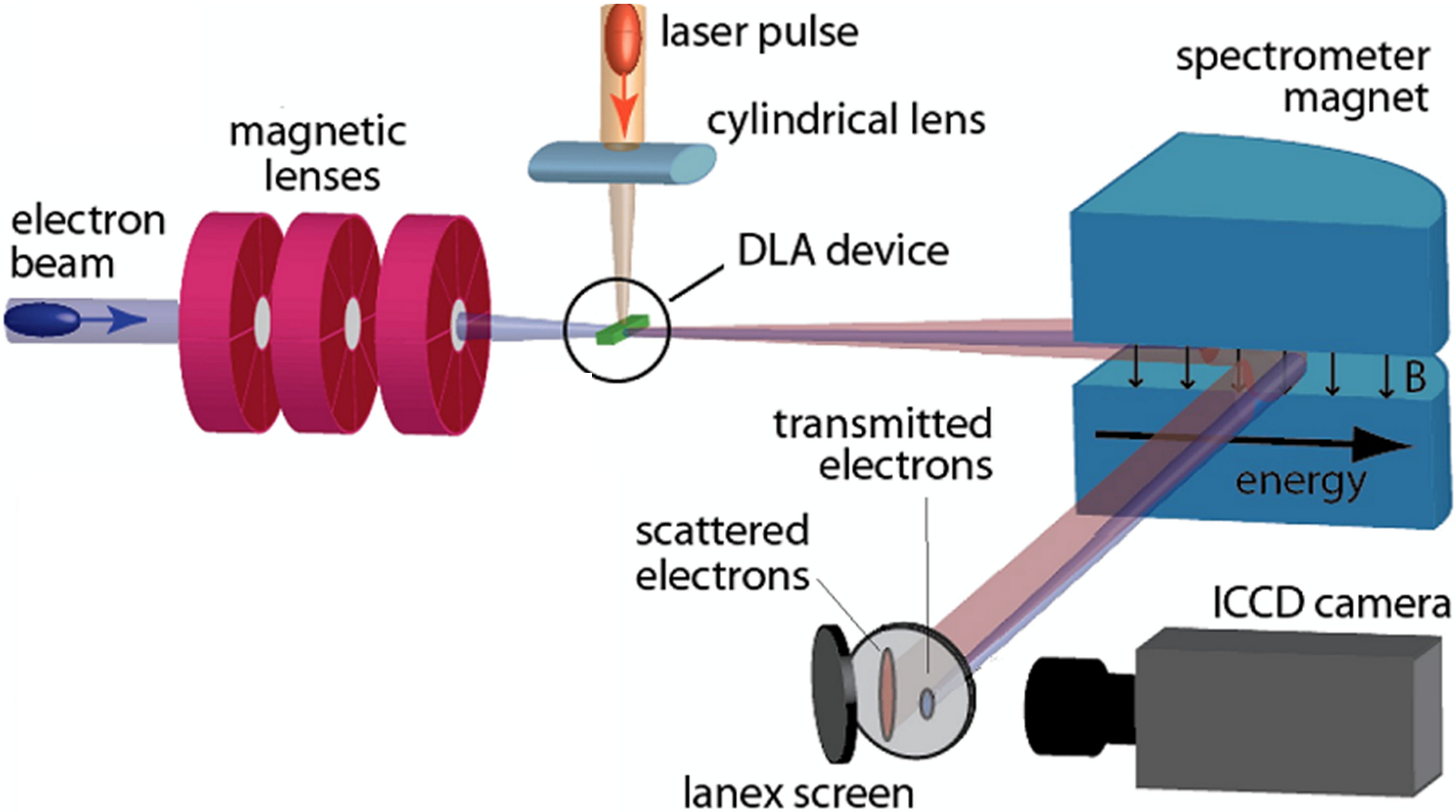
Laser acceleration in free space?



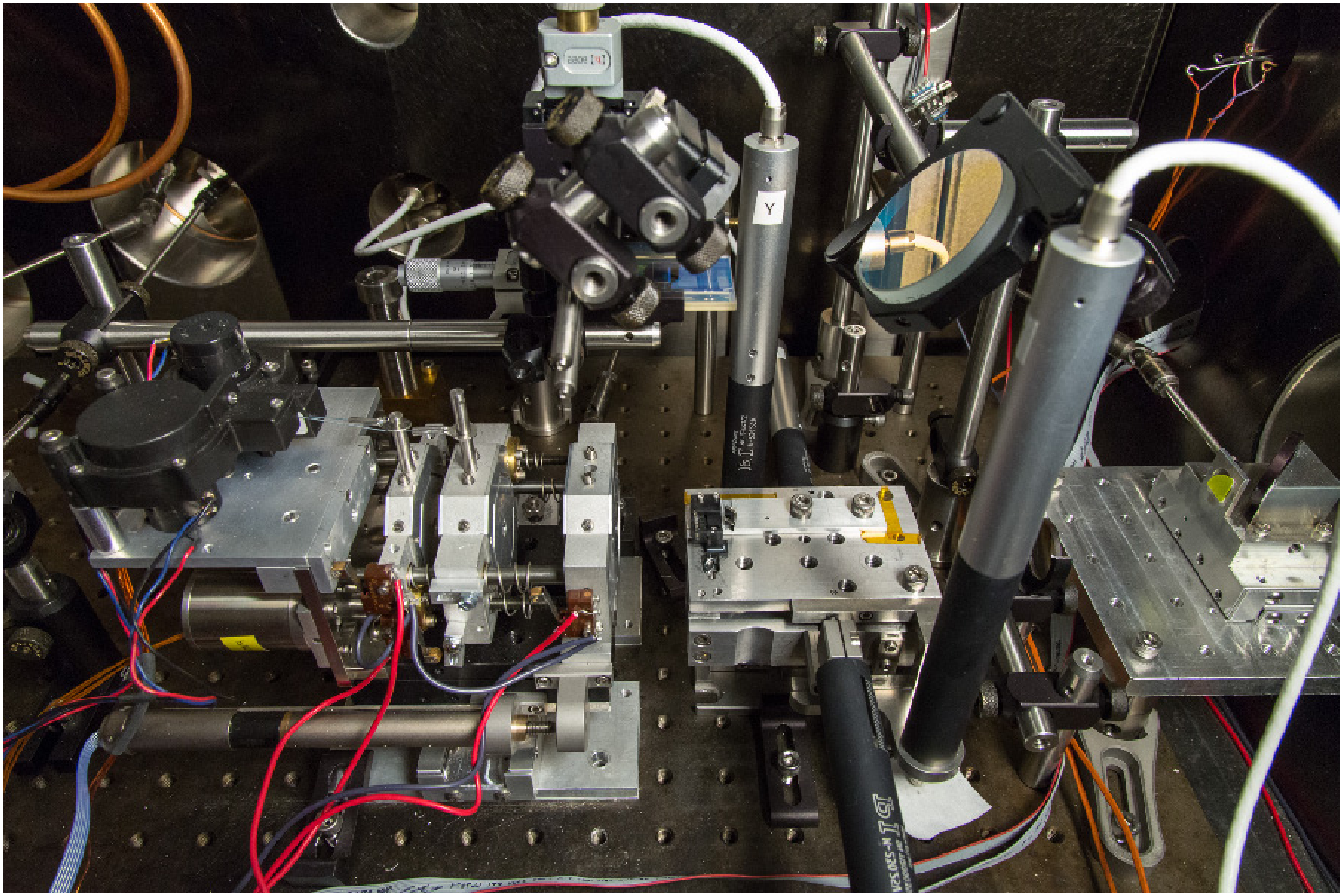
Periodic field reversal inside grating



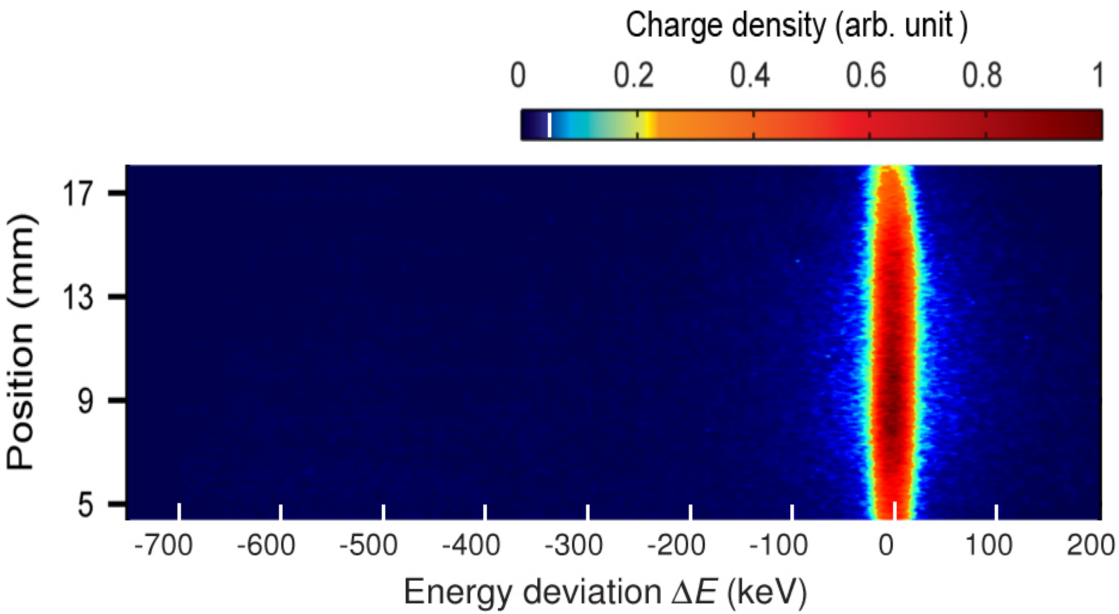
Experiment schematic

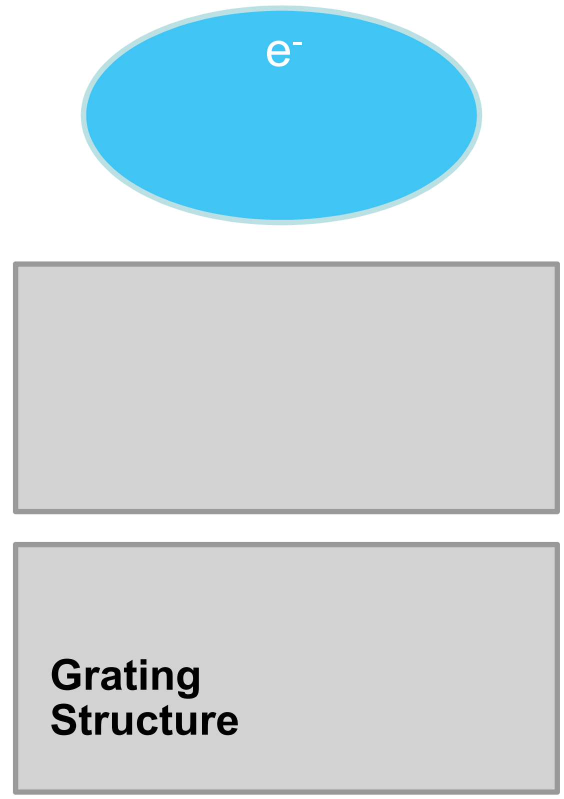


Experimental setup



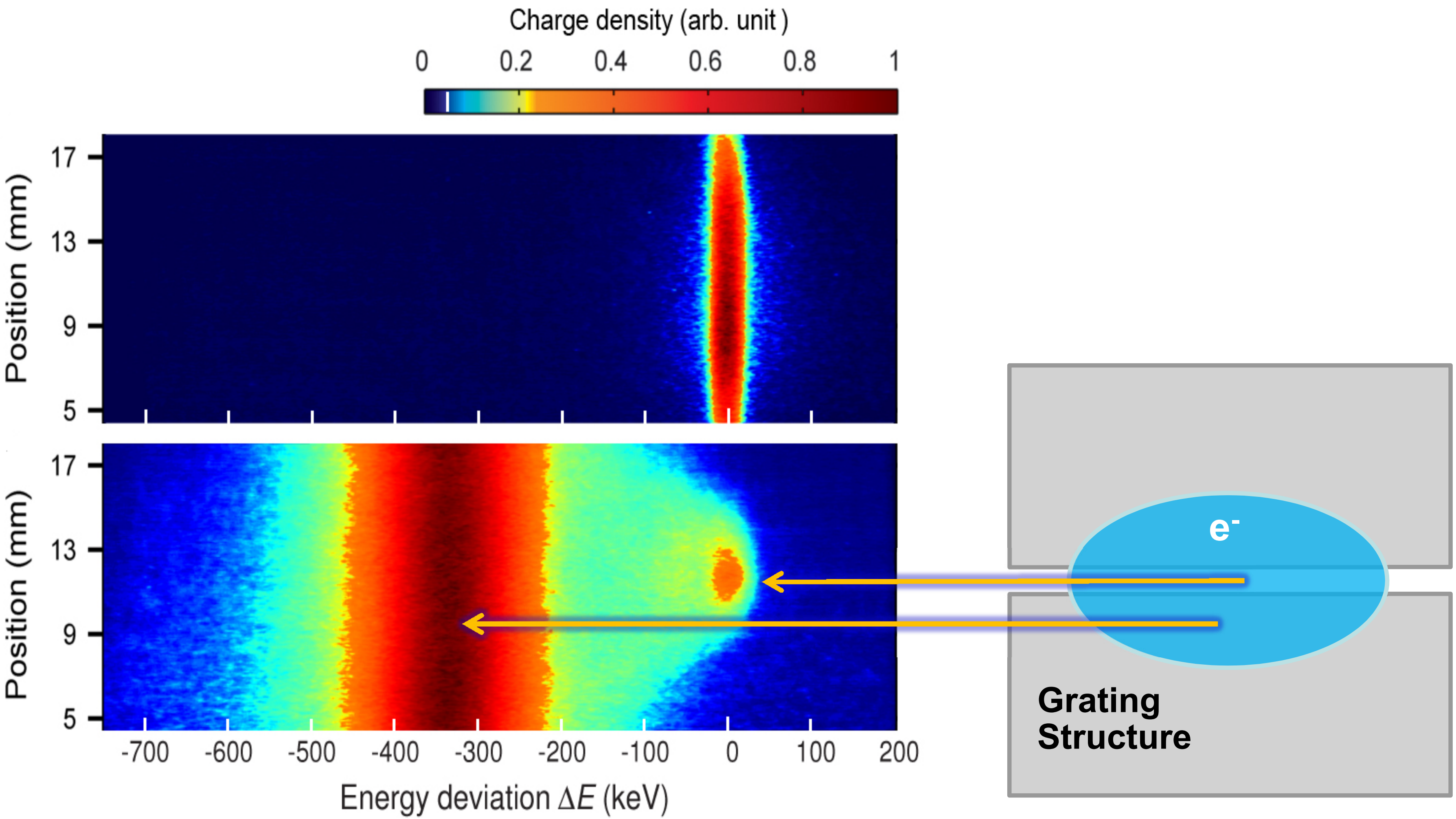
Beam transmission





E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

Beam transmission



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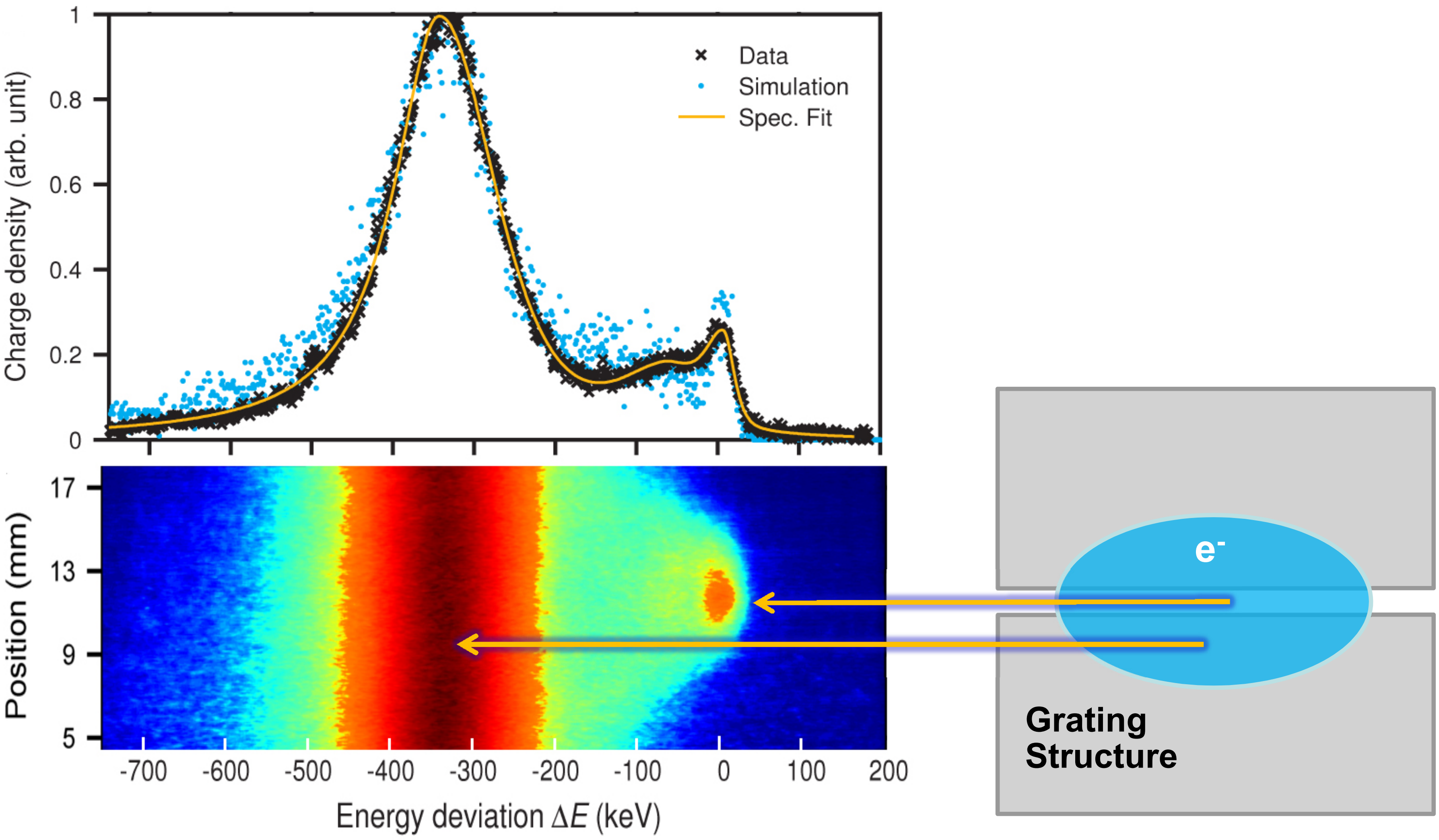
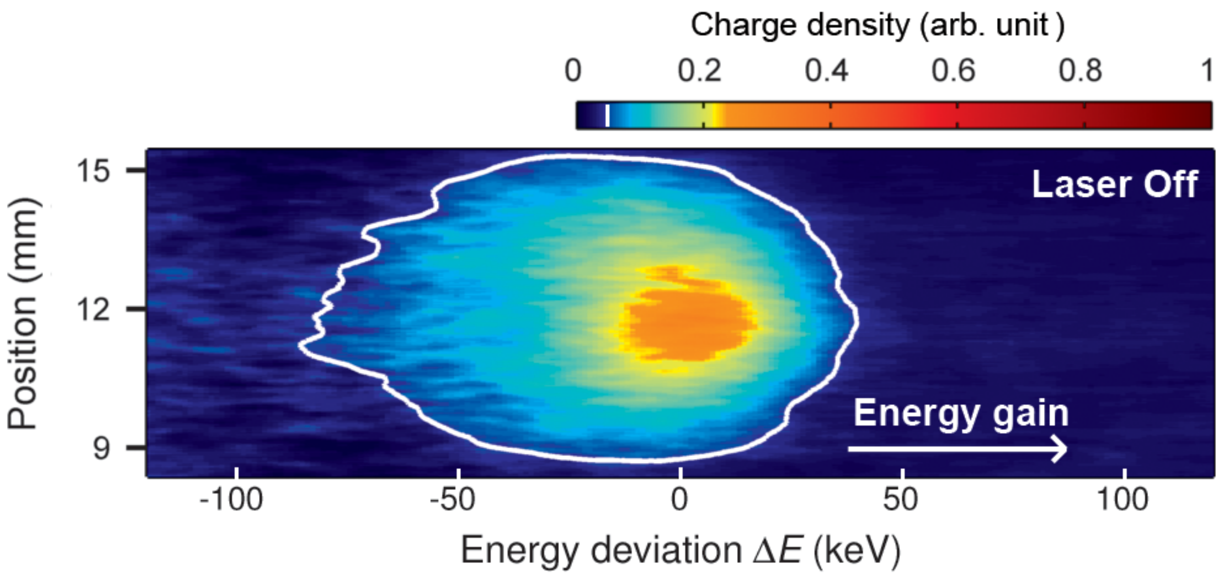
E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

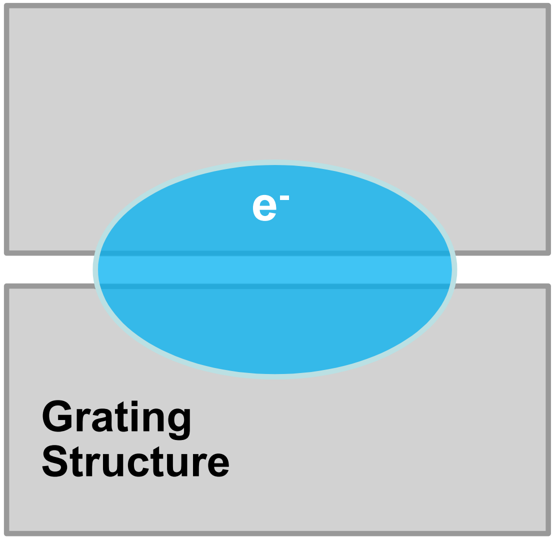
Beam transmission



E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

Laser-induced energy modulation: off





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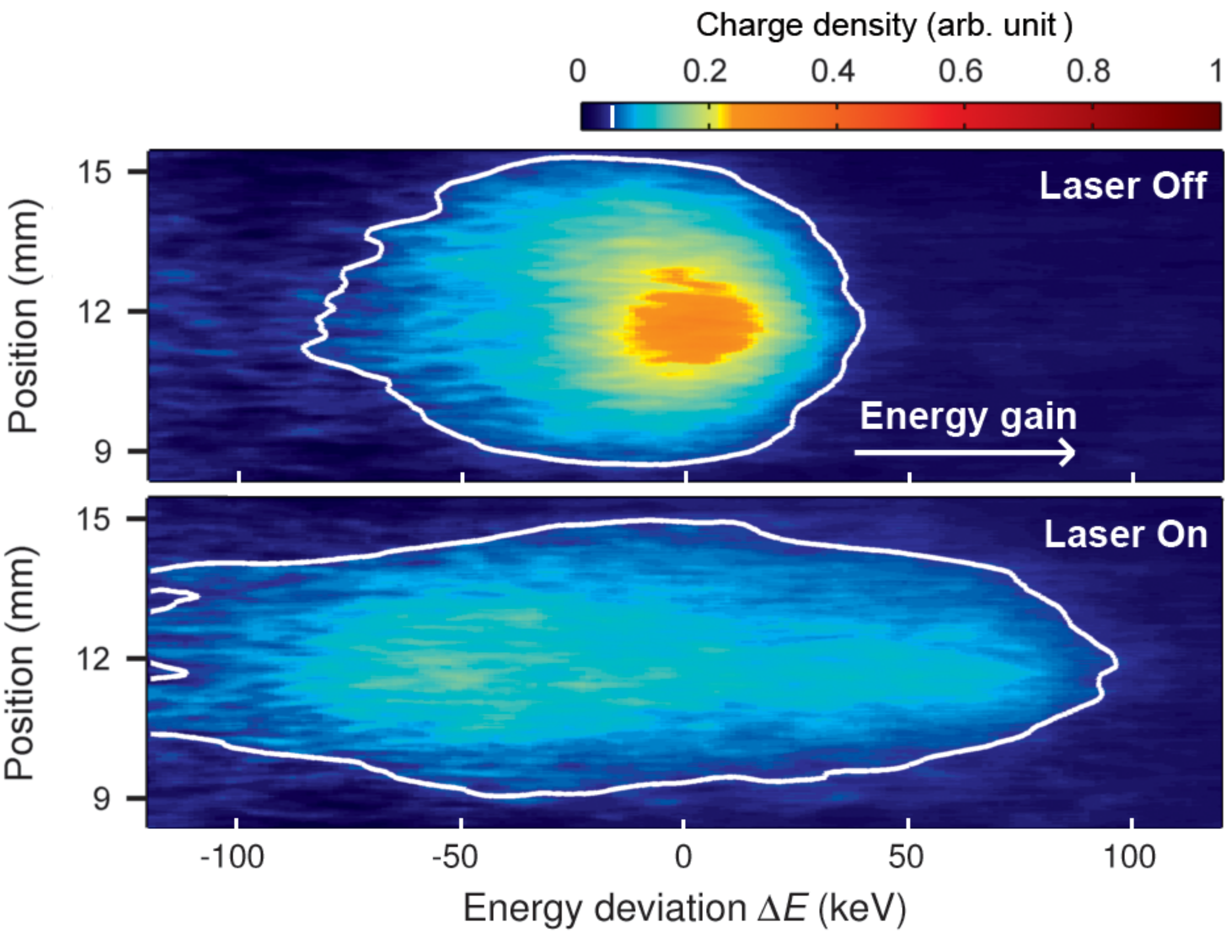
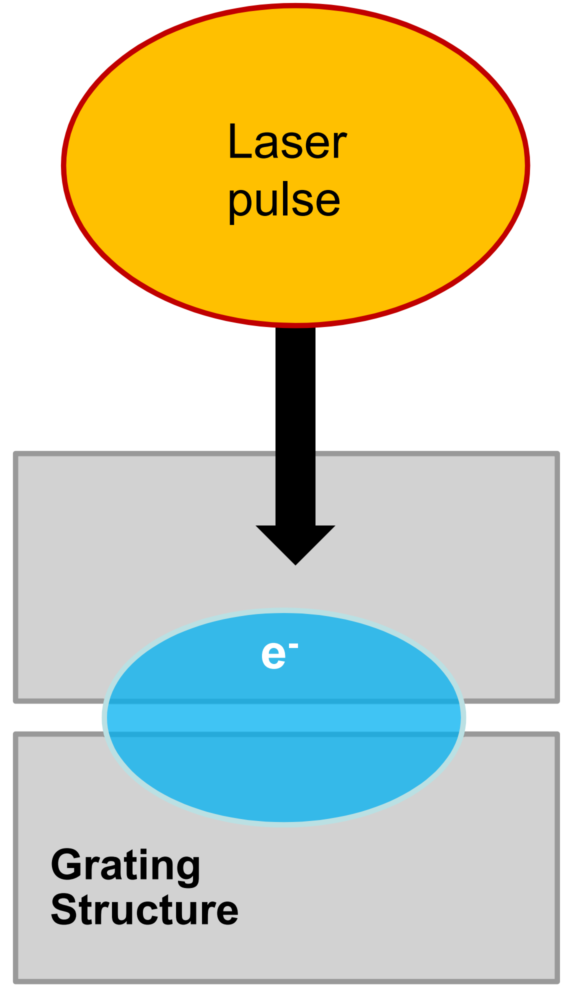
E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

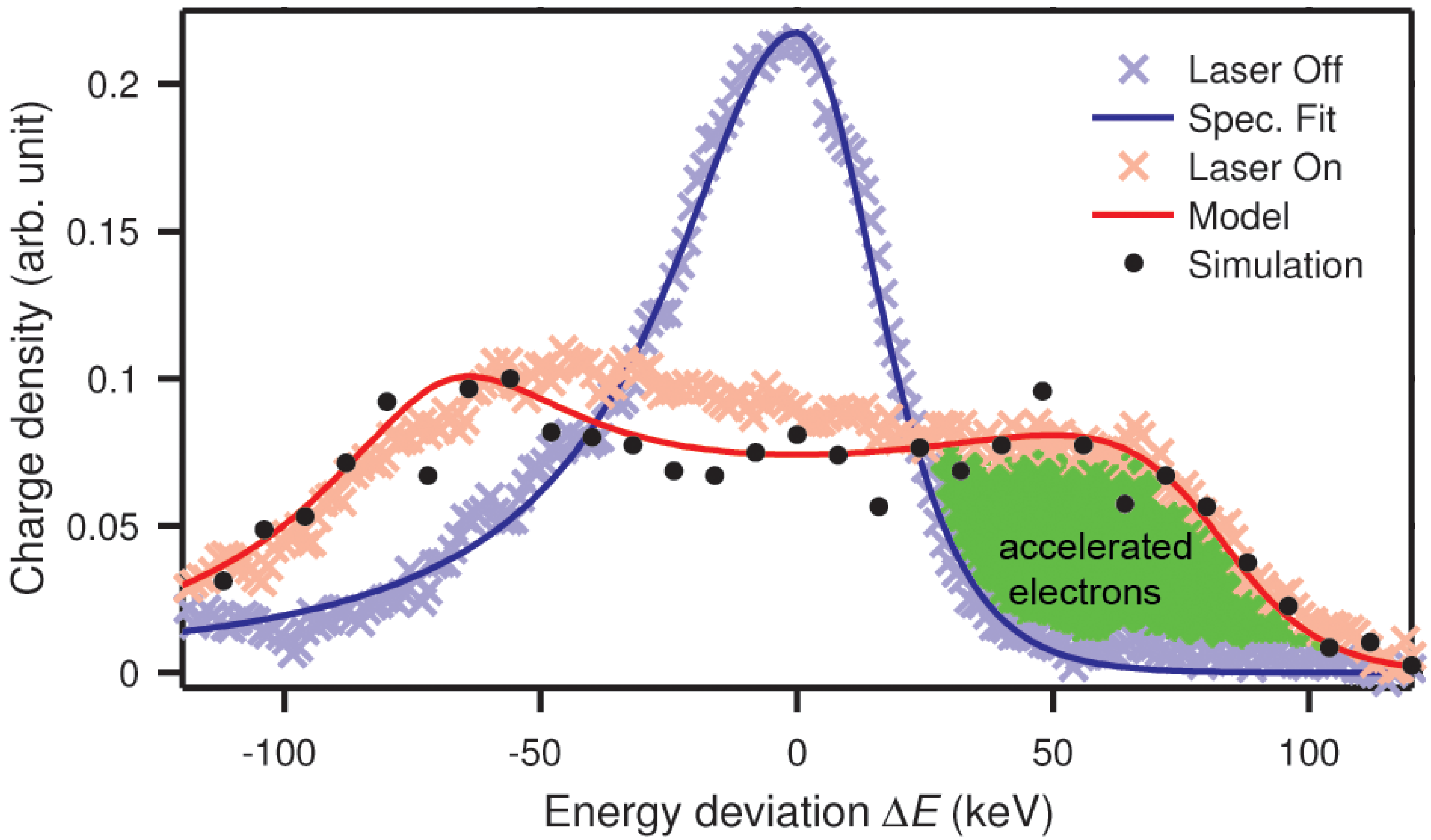
Laser-induced energy modulation: on





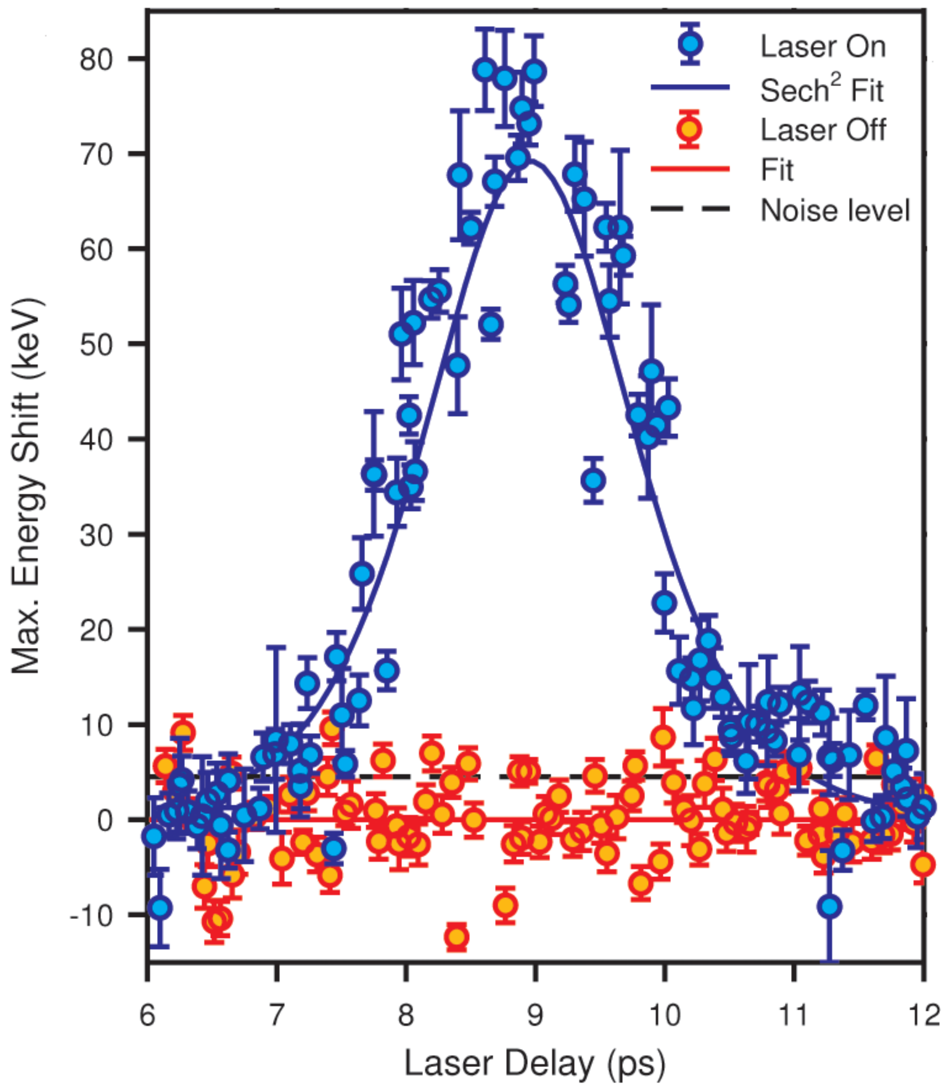
E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

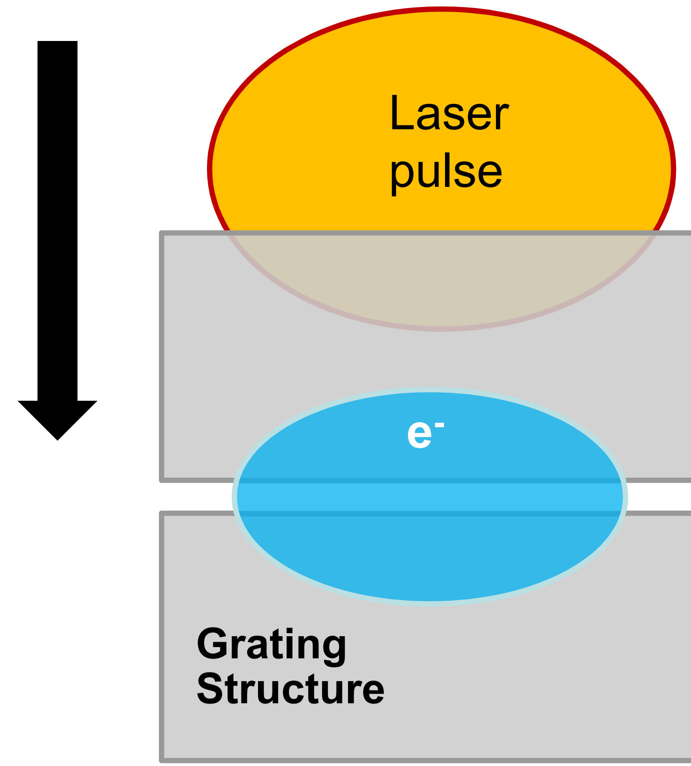
Laser-induced energy modulation



E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

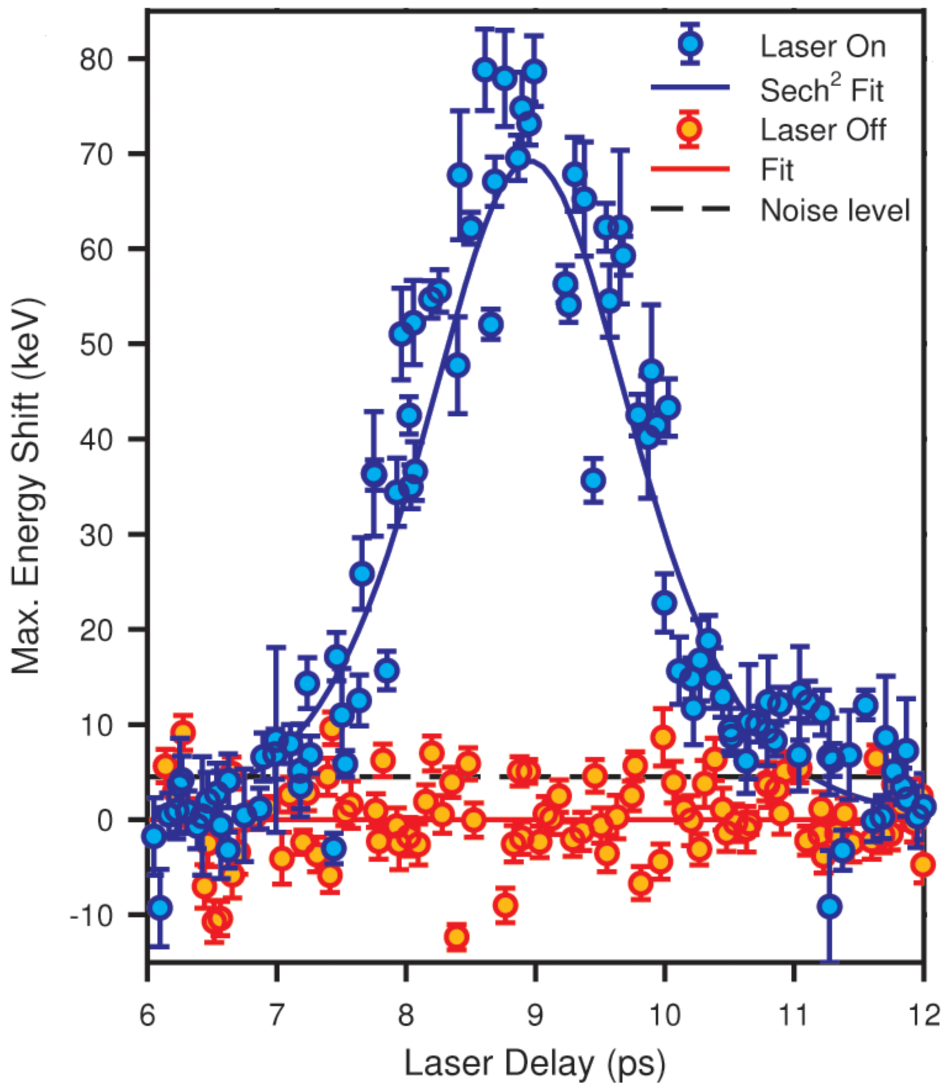
Maximum gradient measurement

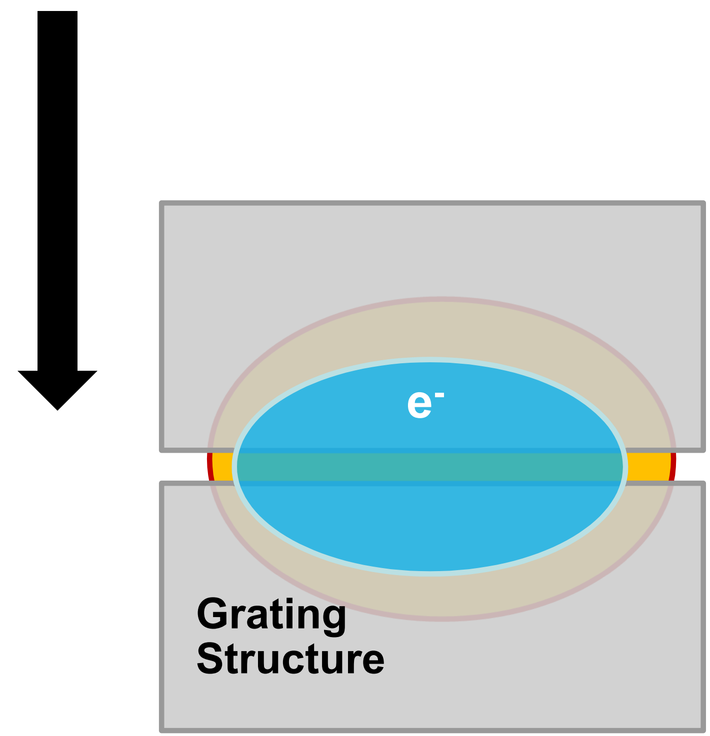




E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

Maximum gradient measurement





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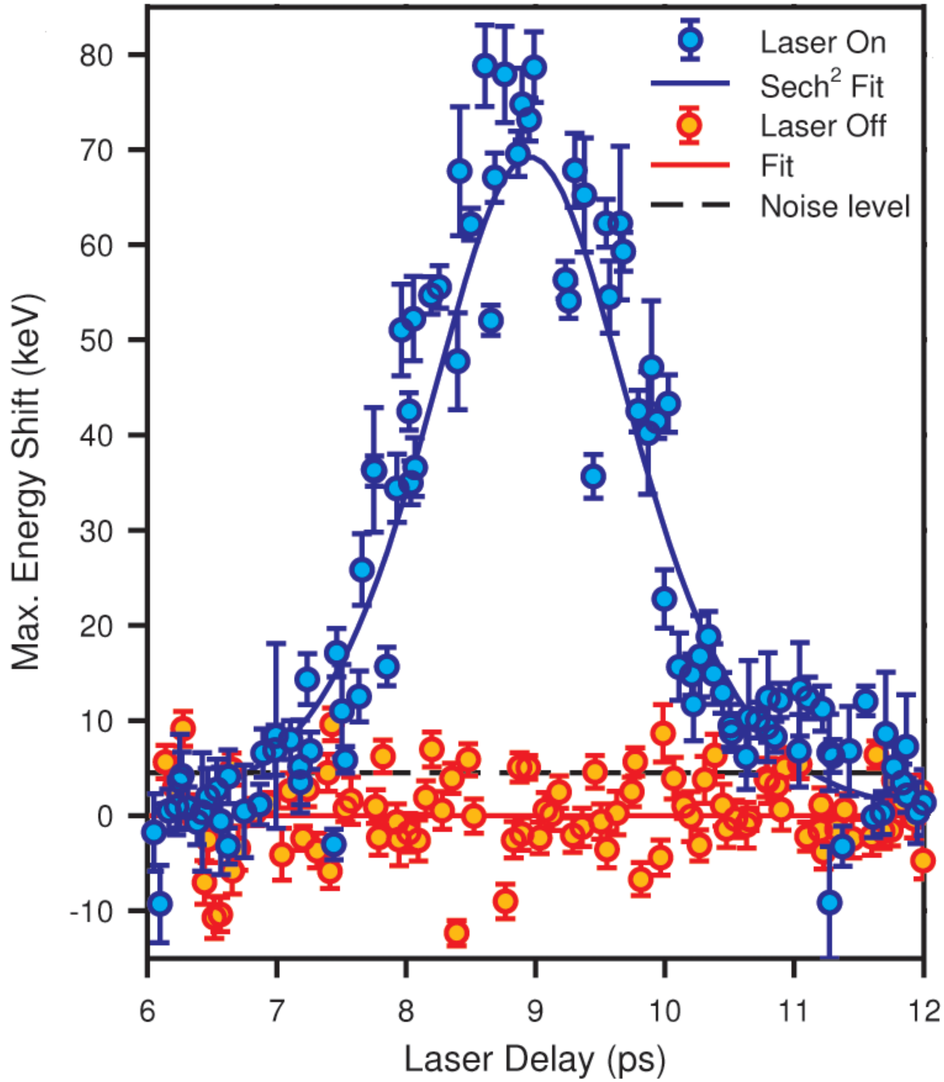
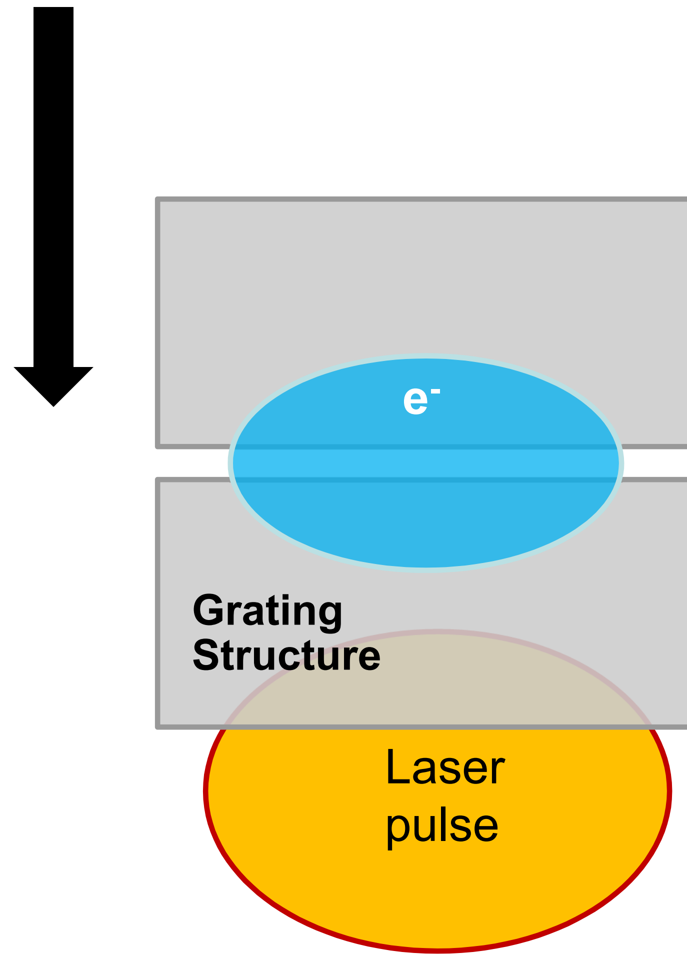
E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

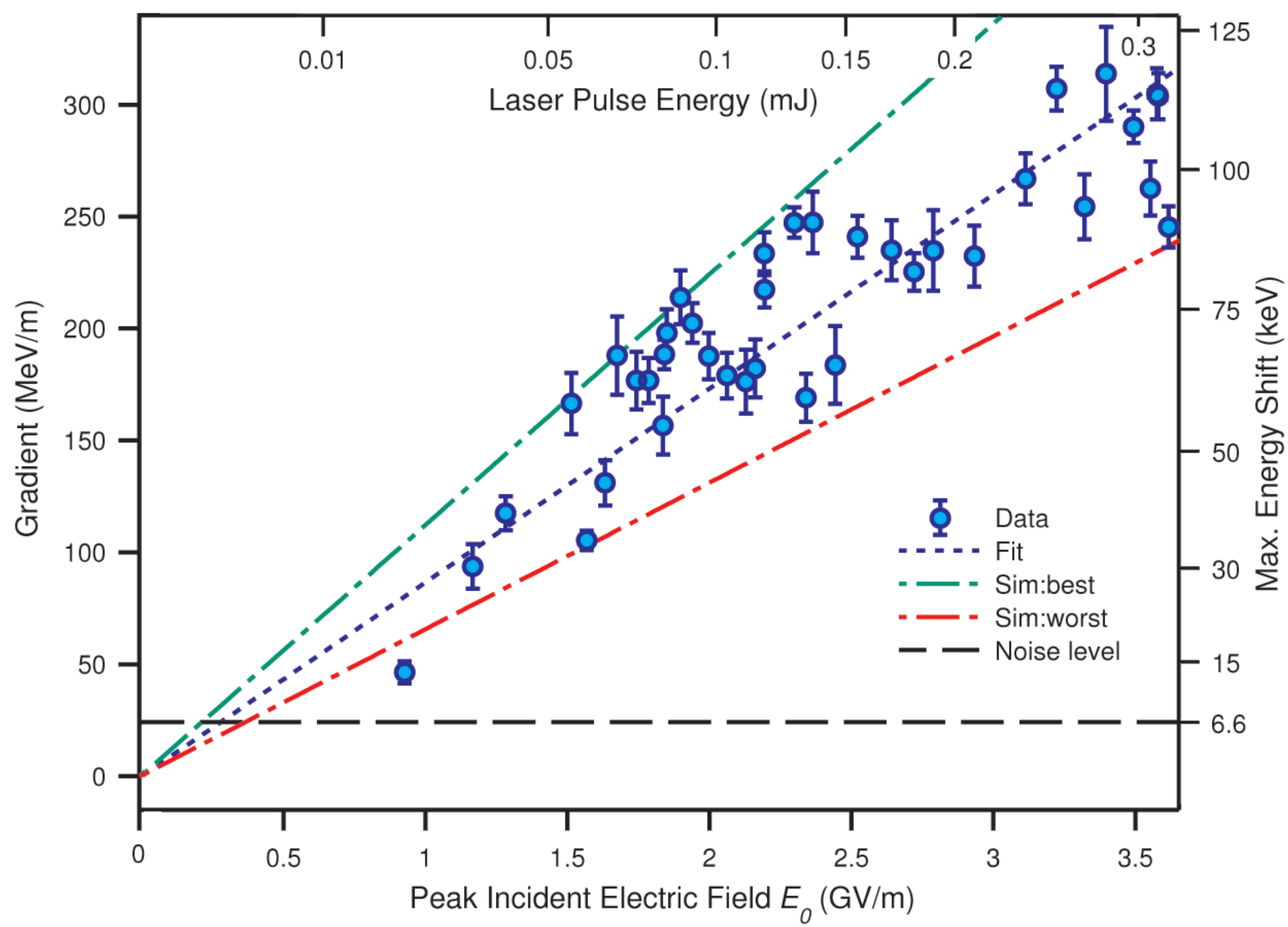
Maximum gradient measurement





E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

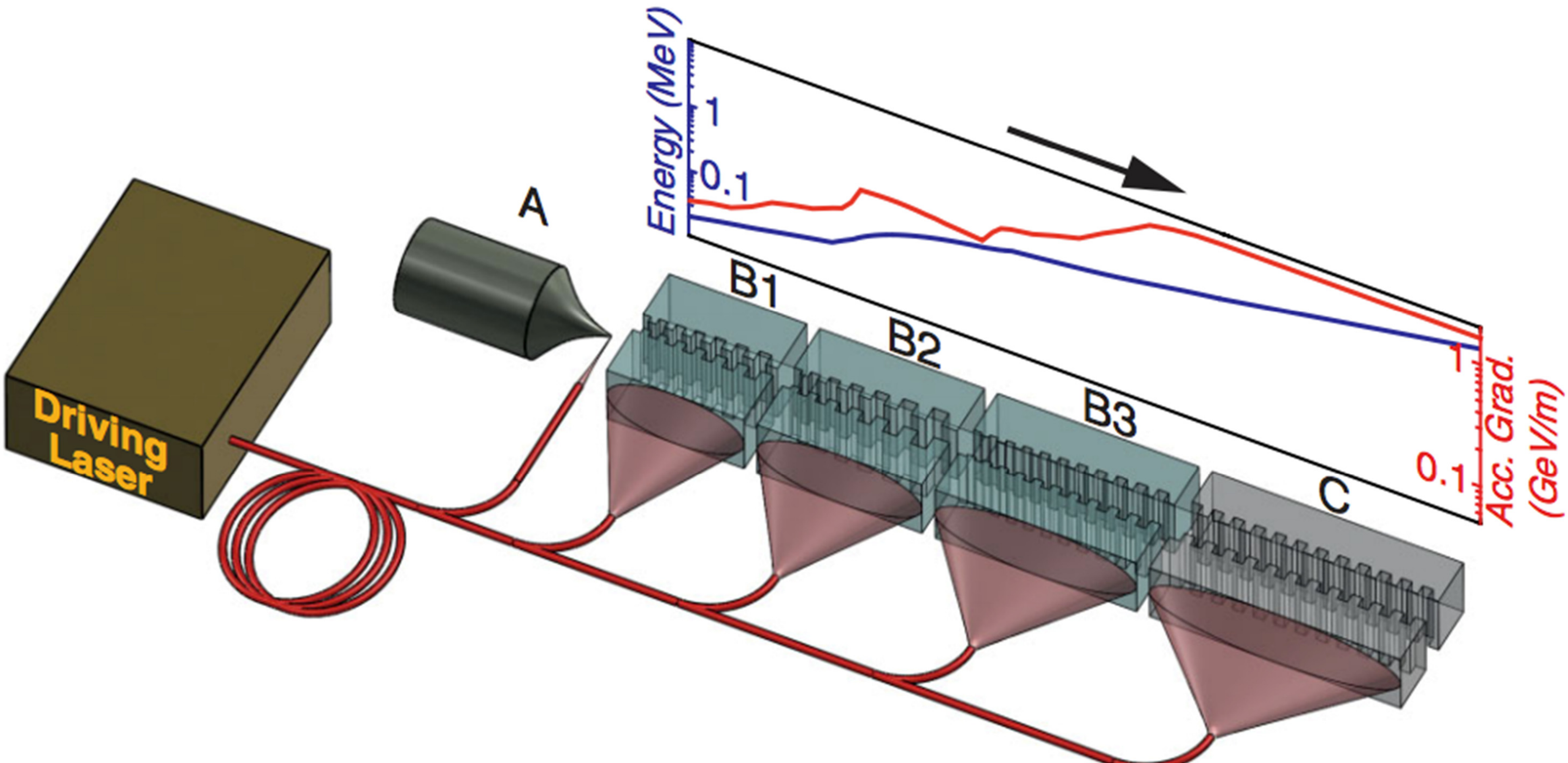
300 MeV/m gradients in first demonstration



E.A. Peralta et al., *Nature* (2013) doi:10.1038/nature12664

What’s next?

Our goal is an all-optical DLA-based LINAC



J. Breuer and P. Hommelhoff, *PRL* **111** 134803 (2013)

Low-β DLA demonstrated at MPQ

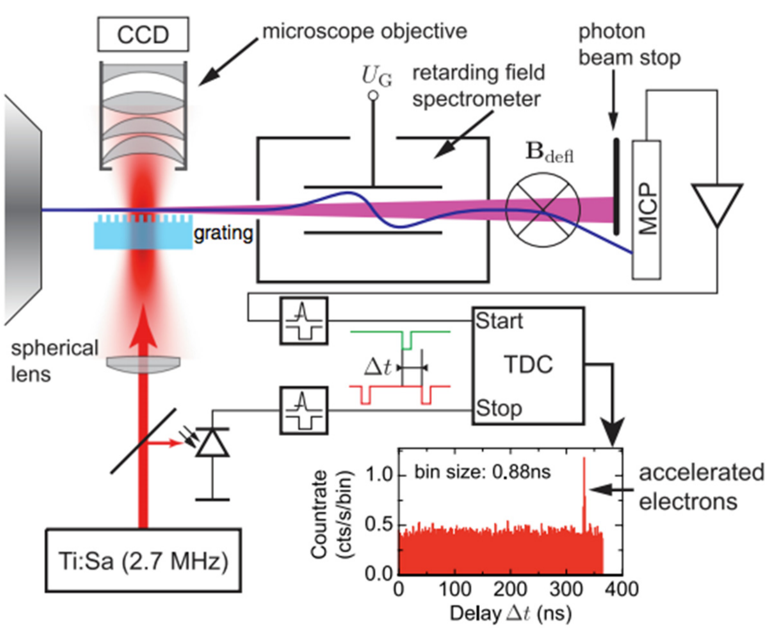
PRL 111, 134803 (2013) PHYSICAL REVIEW LETTERS week ending 27 SEPTEMBER 2013

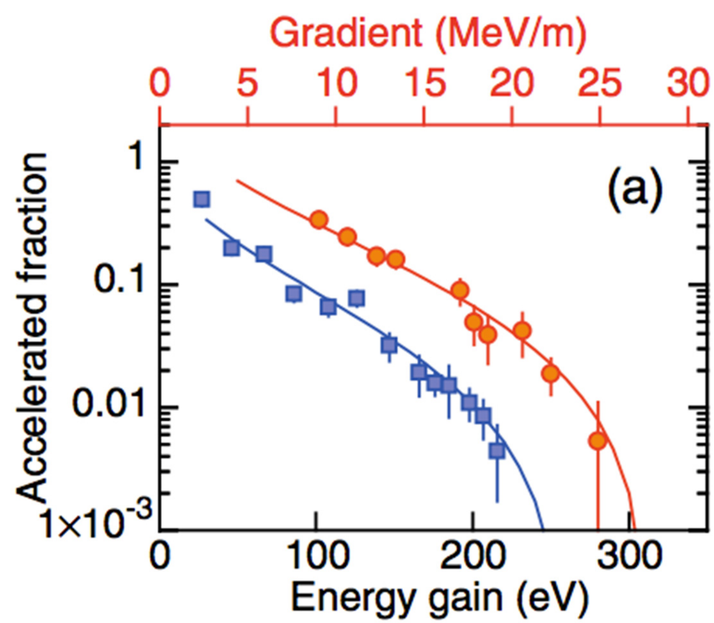
Laser-Based Acceleration of Nonrelativistic Electrons at a Dielectric Structure

John Breuer
Max Planck Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

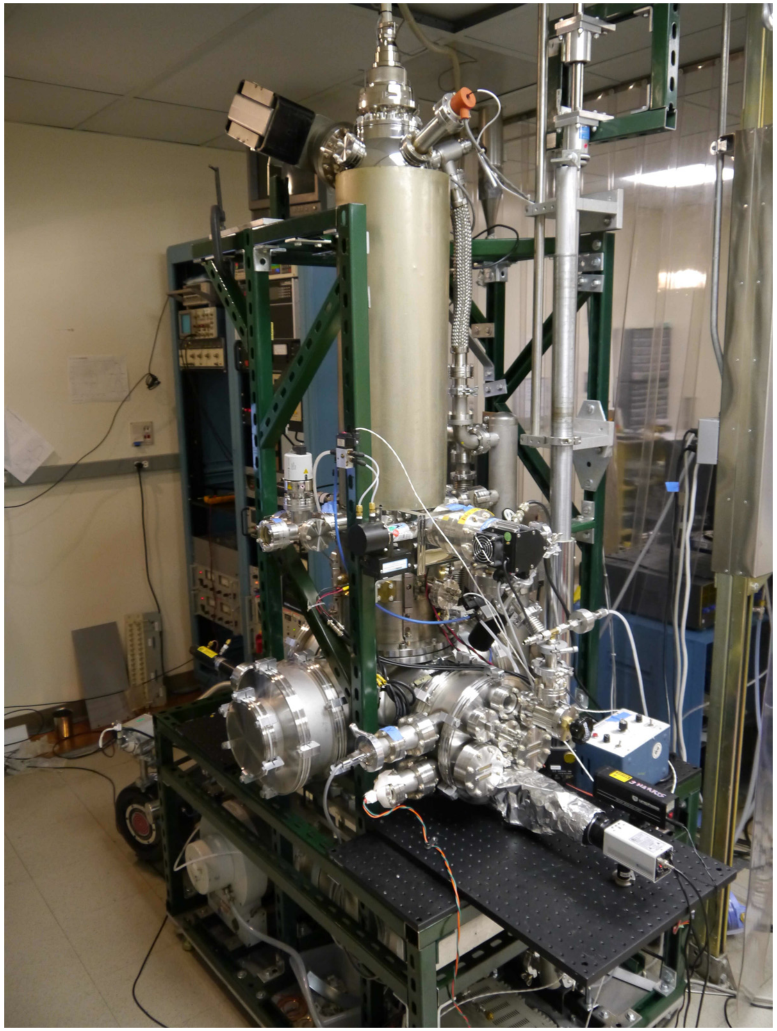
Peter Hommelhoff*
Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, Staudtstrasse 1, 91058 Erlangen, Germany and Max Planck Institute of Quantum Optics, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany
(Received 15 July 2013; published 27 September 2013)

A proof-of-principle experiment demonstrating dielectric laser acceleration of *nonrelativistic* electrons in the vicinity of a fused-silica grating is reported. The grating structure is utilized to generate an electro-





Low-β DLA efforts at Stanford



- LaB6 thermal source (10-100keV)
- Dual side illumination capability.
- 6-axis sample holder.
- Backscattered SEM imaging mode for quickly aligning samples.
- 90 deg. bending magnet spectrometer with ~4eV resolution.

(Ken Leedle, Prof. Jim Harris)

DLA-based beam position monitor

March 1, 2012 / Vol. 37, No. 5 / OPTICS LETTERS 975

Design of a subnanometer resolution beam position monitor for dielectric laser accelerators

Ken Soong* **and Robert L. Byer**
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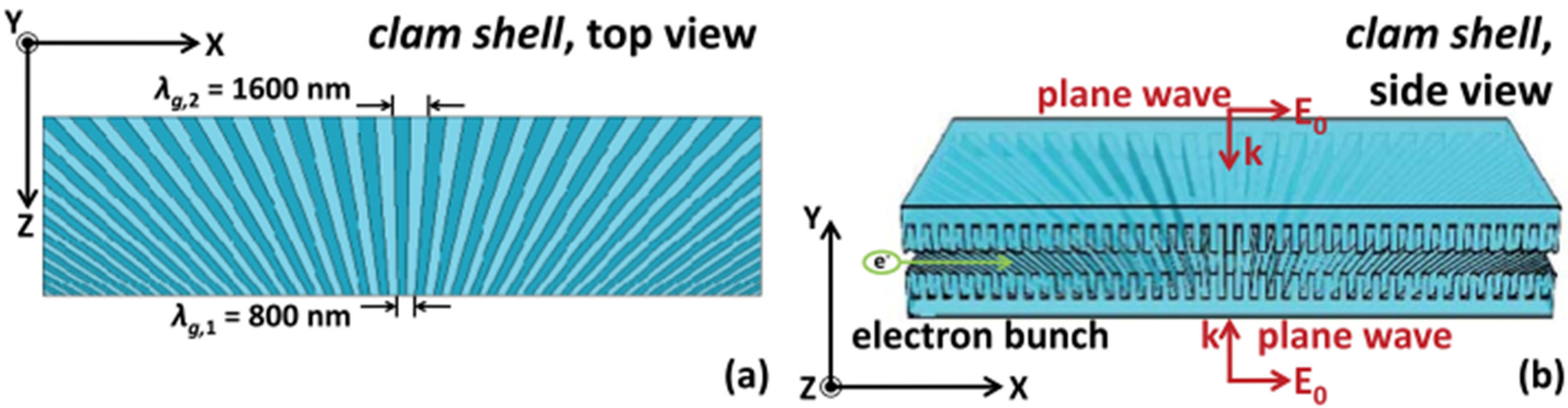
**Corresponding author: KenSoong@SLAC.Stanford.edu*

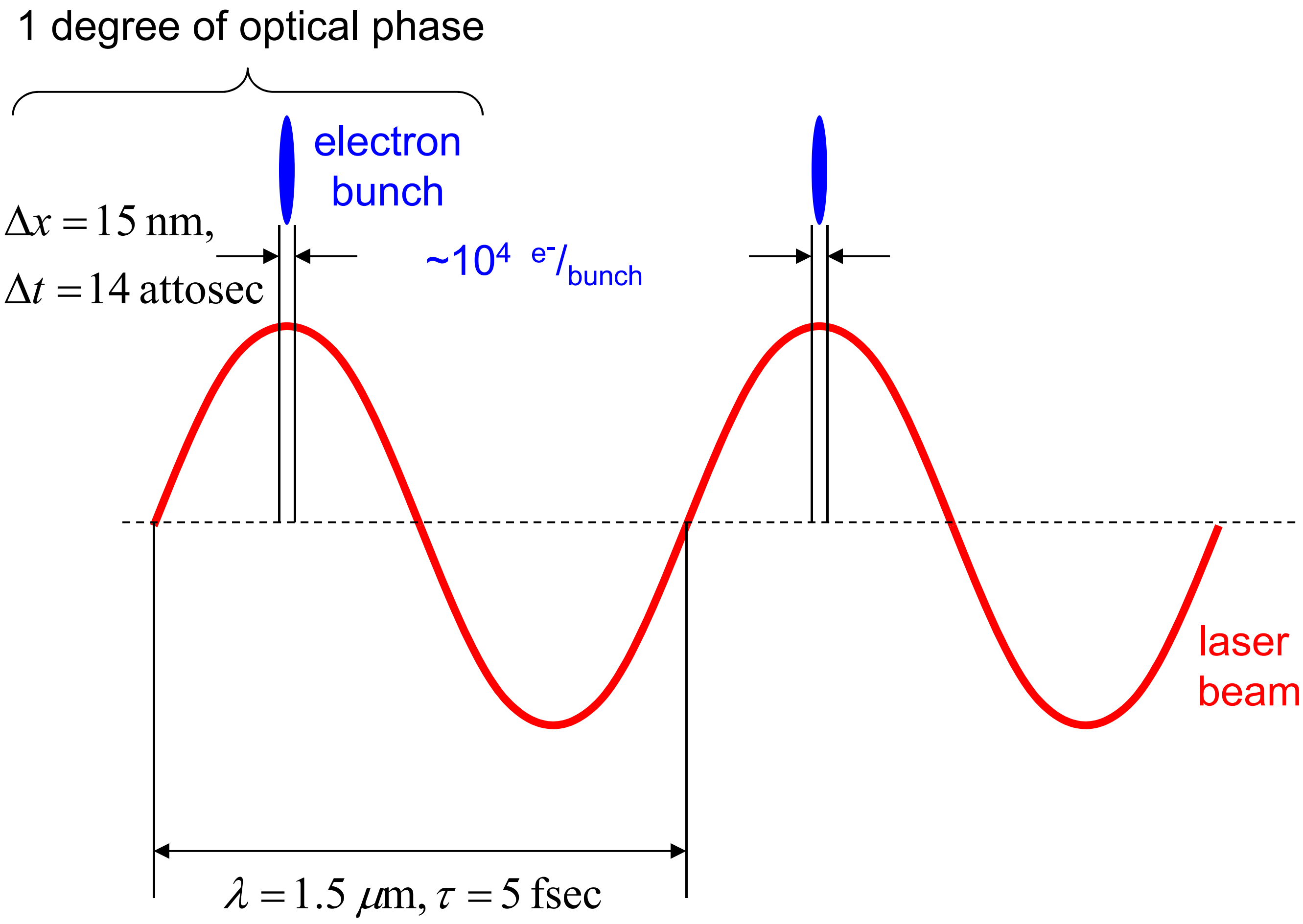
Received September 8, 2011; revised January 20, 2012; accepted January 21, 2012;
posted January 23, 2012 (Doc. ID 154270); published March 1, 2012

We present a new concept for a beam position monitor with the unique ability to map particle beam position to a measurable wavelength. Coupled with an optical spectrograph, this beam position monitor is capable of subnanometer resolution. We describe one possible design, and through finite-element frequency-domain simulations, we show a resolution of 0.7 nm. Because of its high precision and ultracompact form factor, this device is ideal for future x-ray sources and laser-driven particle accelerators "on a chip."
OCIS codes: 040.1880, 050.2770, 120.0120, 220.2740.



Check out Ken Soong's poster!

Attosec-scale electron bunches



Conclusion

- We have developed and fabricated a variety of prototype accelerator structures.
- We have successfully performed a proof of concept demonstration with very promising results.
- We have created a new setup for testing of low-β structures at Stanford.
- We have developed several designs for DLA-based components that are required to operate a full LINAC
- Experimental efforts are currently underway to demonstrate the BPM structure at SLAC (see Ken Soong's poster!)

Acknowledgements – Thank you!

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Prof. Olav Solgaard (co-PI)
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Dr. Esin Sozer
Josh McNeur

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Dr. Ben Cowan
Dr. Brian Schwartz

SLAC National Accelerator Laboratory
Dr. Joel England (Proj. Mgr.)
Dr. Bob Noble
Dr. Ziran Wu
Dieter Waltz
Prof. Minghao Qi (visiting scientist)