Narrow-band THz emission from laser modulated electron beams

Dao Xiang, for the Echo-7 group, SLAC

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Workshop on THz Sources for Time Resolved Studies of Matter, ANL

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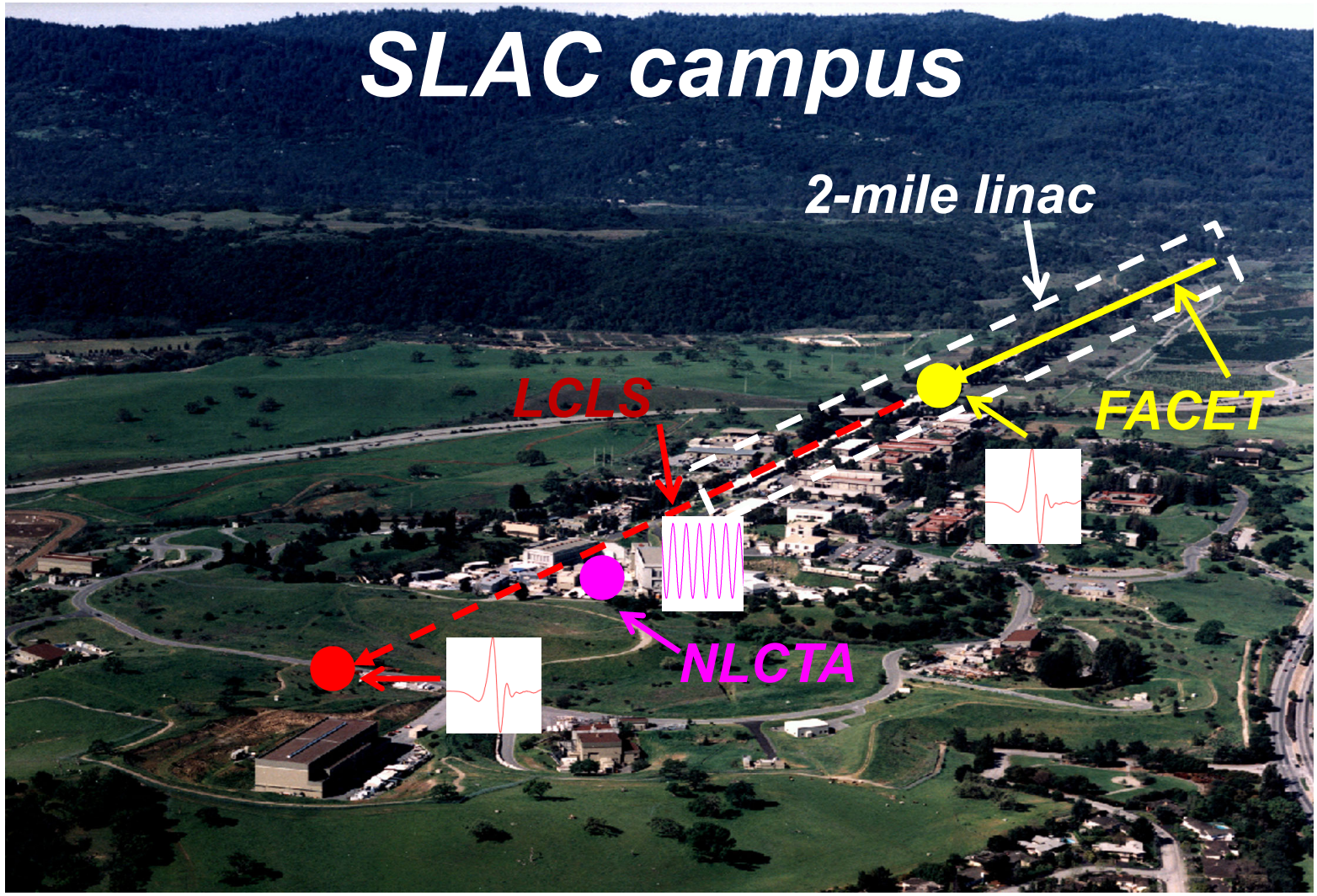
U.S. DEPARTMENT OF ENERGY | Office of Science

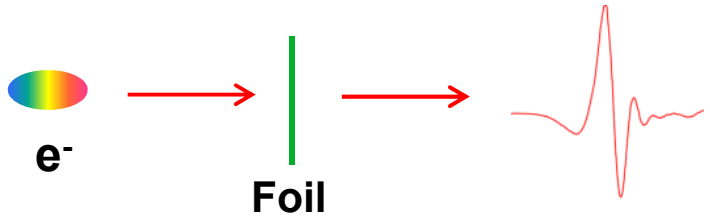
E-beam based THz sources @ SLAC

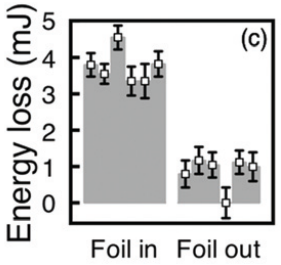


E-beam based THz sources

Broadband THz radiation

- Use single ultra-short bunch



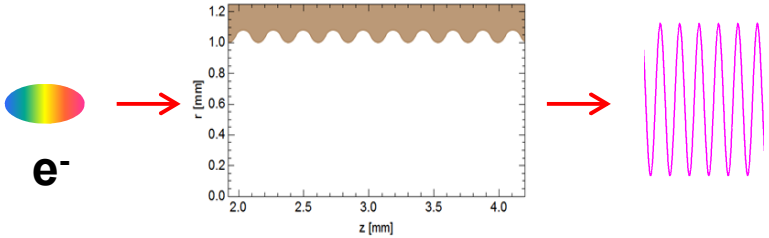


~3 mJ THz radiation from a 350 pC e-beam

Daranciang et al., APL, 2011

Narrowband THz radiation

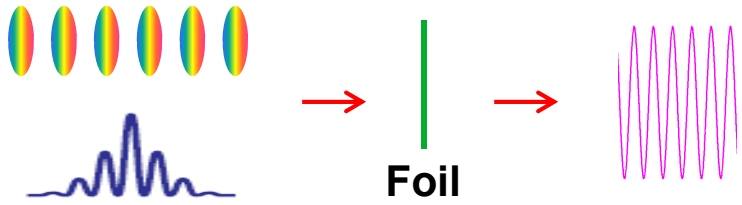
- Use single ultra-short bunch



Undulator, corrugated pipe or a pipe with a dielectric liner

See Karl Bane's talk

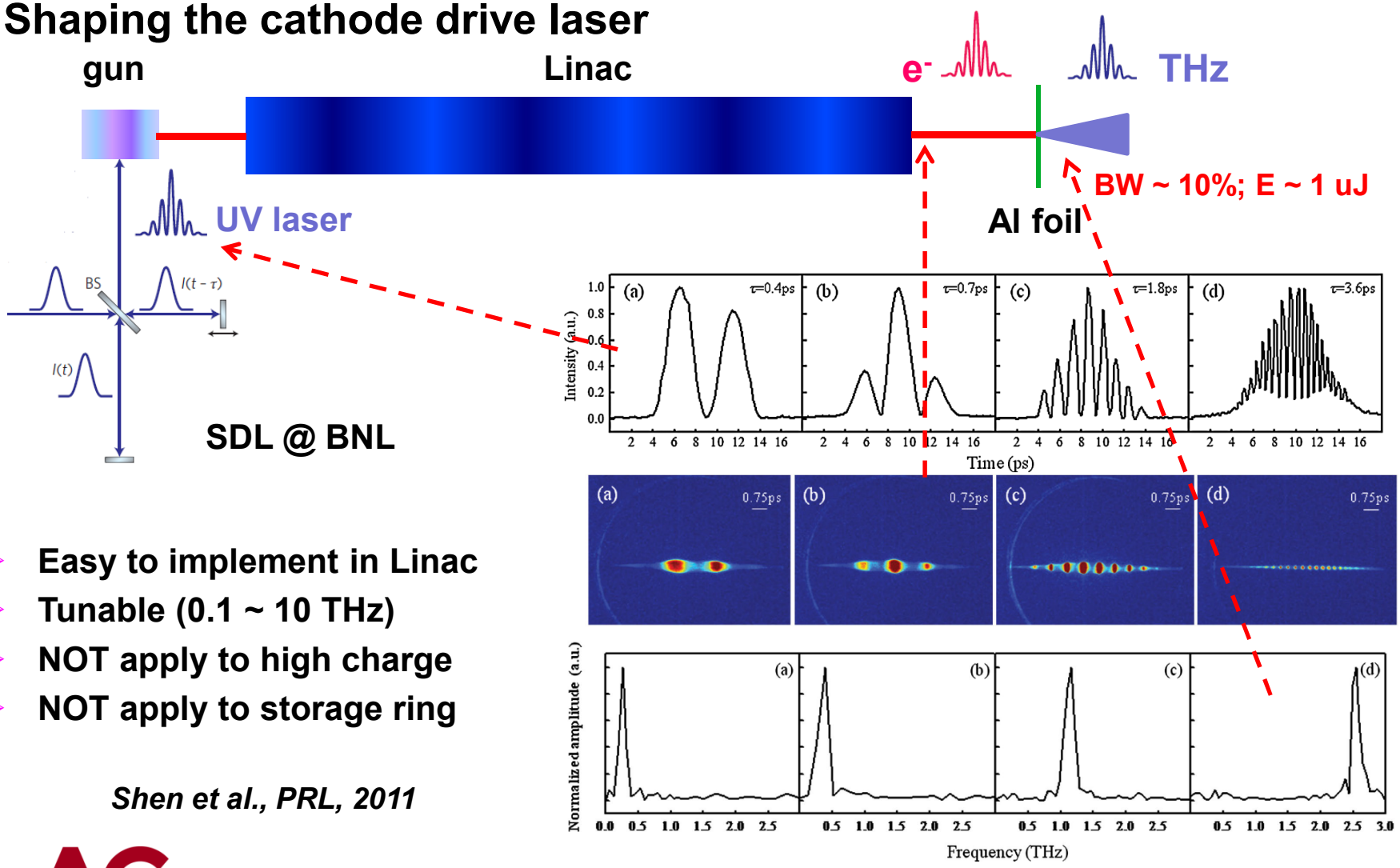
- Use density-modulated e-beam



- Modulate cathode drive laser
- Emittance exchange
- Modulate beam with optical lasers

E-beam based narrowband THz

- **Shaping the cathode drive laser**



- Easy to implement in Linac
- Tunable (0.1 ~ 10 THz)
- NOT apply to high charge
- NOT apply to storage ring

Shen et al., PRL, 2011

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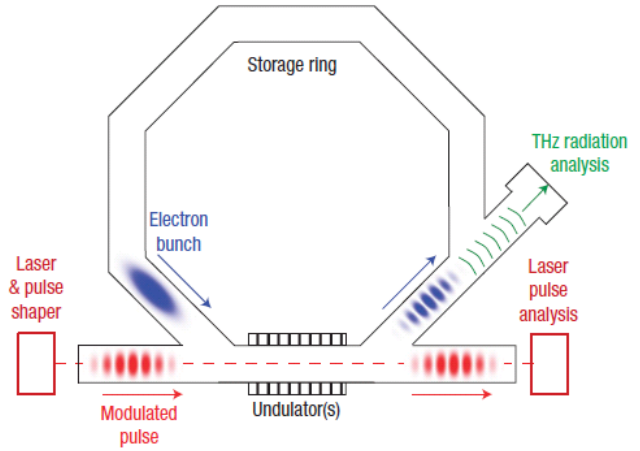
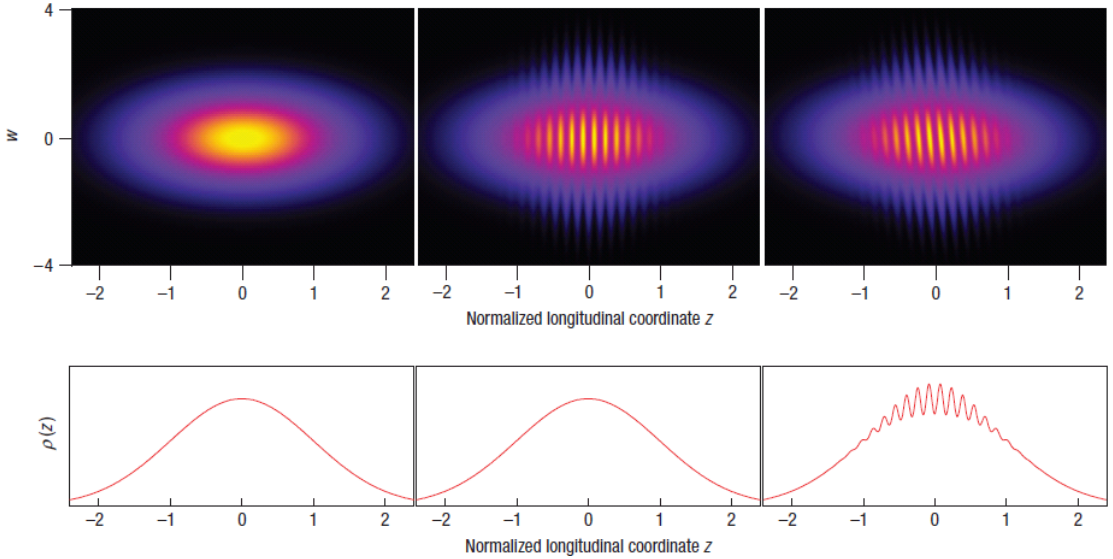
E-beam based narrowband THz

- **Shaping the seed laser**

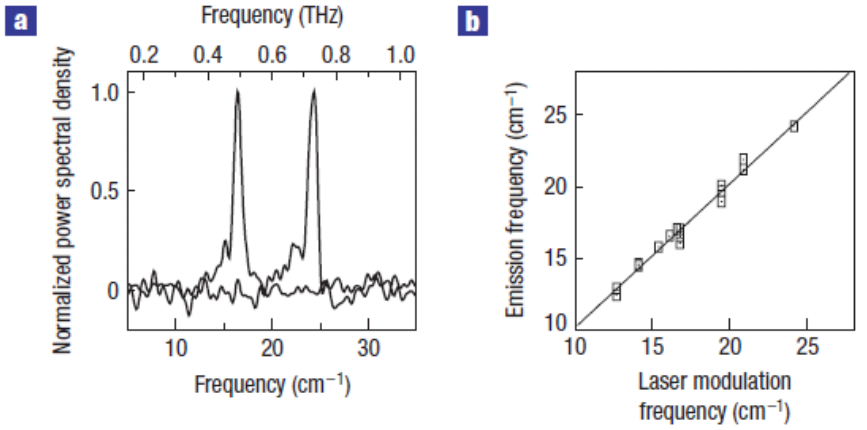


UVSOR



- **Generate THz modulation in seed laser envelope**
- **Convert energy modulation into density modulation**

Bielawski *et al.*, Nature. Phys, 2008



Narrow-band THz from laser modulated e-beam

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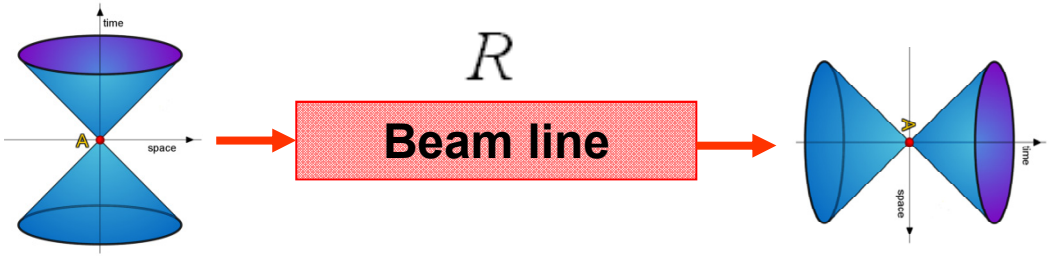
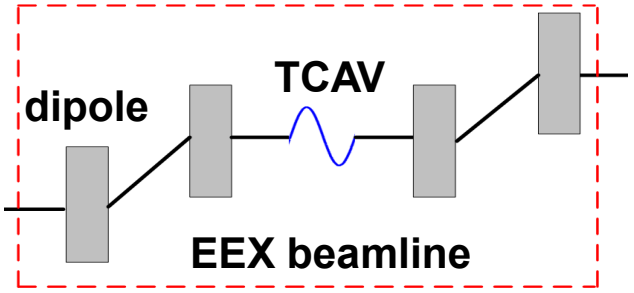
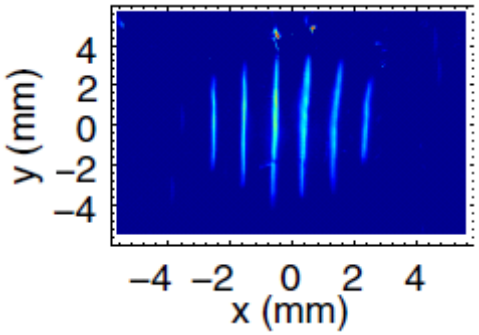
E-beam based narrowband THz

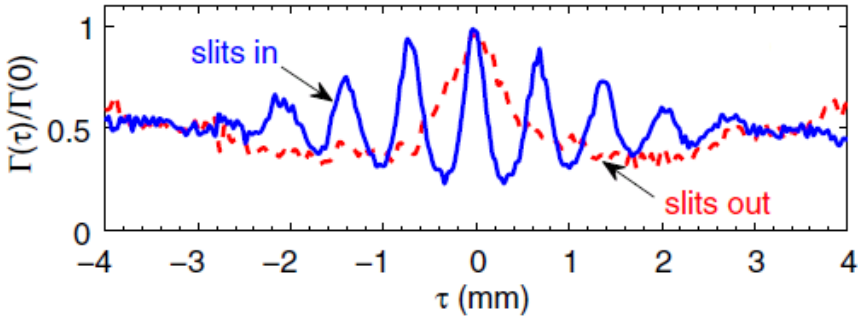
- Emittance exchange (EEX)



$$\begin{pmatrix} x \\ x' \\ z \\ \delta \end{pmatrix} = \begin{pmatrix} 0 & 0 & R_{13} & R_{14} \\ 0 & 0 & R_{23} & R_{24} \\ R_{31} & R_{32} & 0 & 0 \\ R_{41} & R_{42} & 0 & 0 \end{pmatrix} \begin{pmatrix} x_0 \\ x_0' \\ z_0 \\ \delta_0 \end{pmatrix}$$







Sun et al., PRL, 2010

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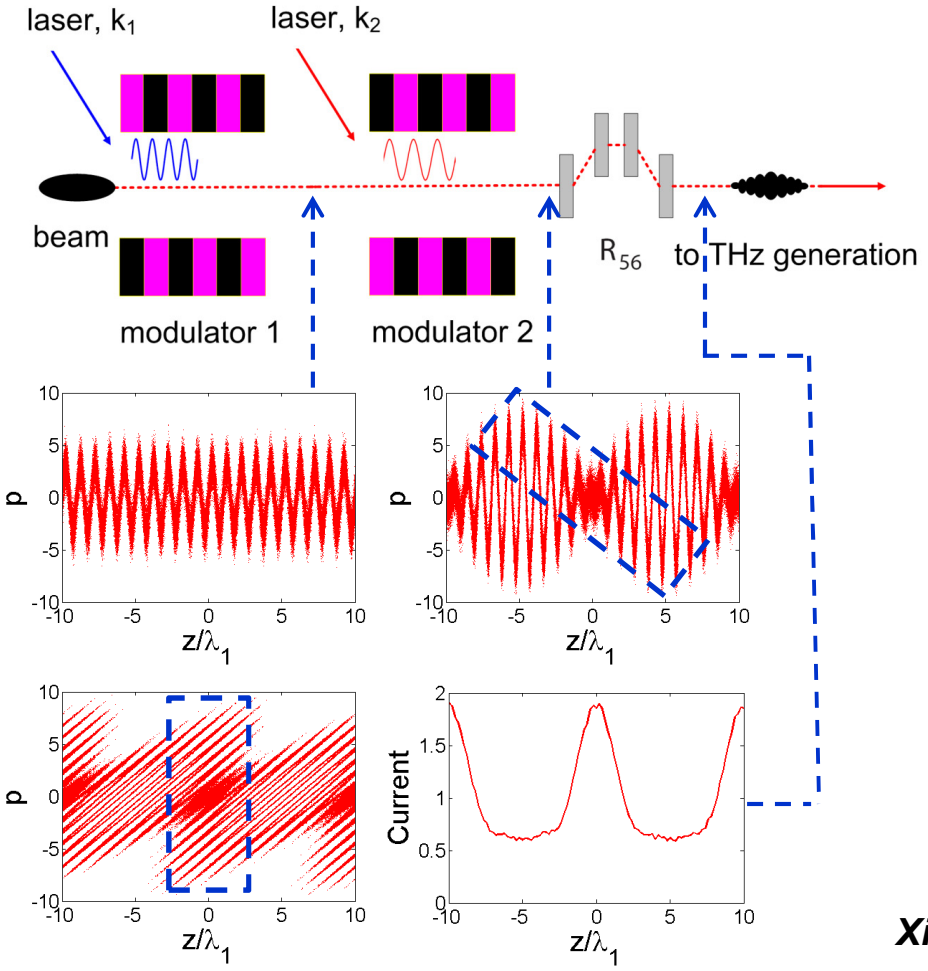
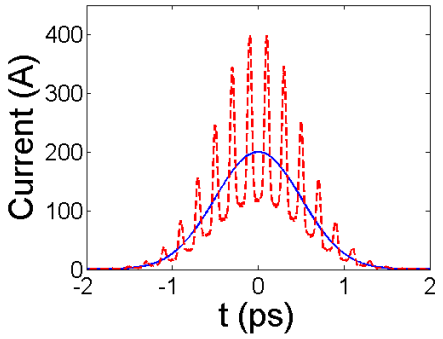
Narrow-band THz from laser modulated e-beam

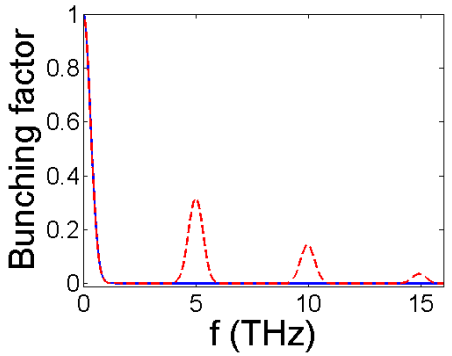
E-beam based narrowband THz

- **DFG with relativistic e-beam as the nonlinear medium**





Beam current



Radiation spectrum

Laser1: 770 nm

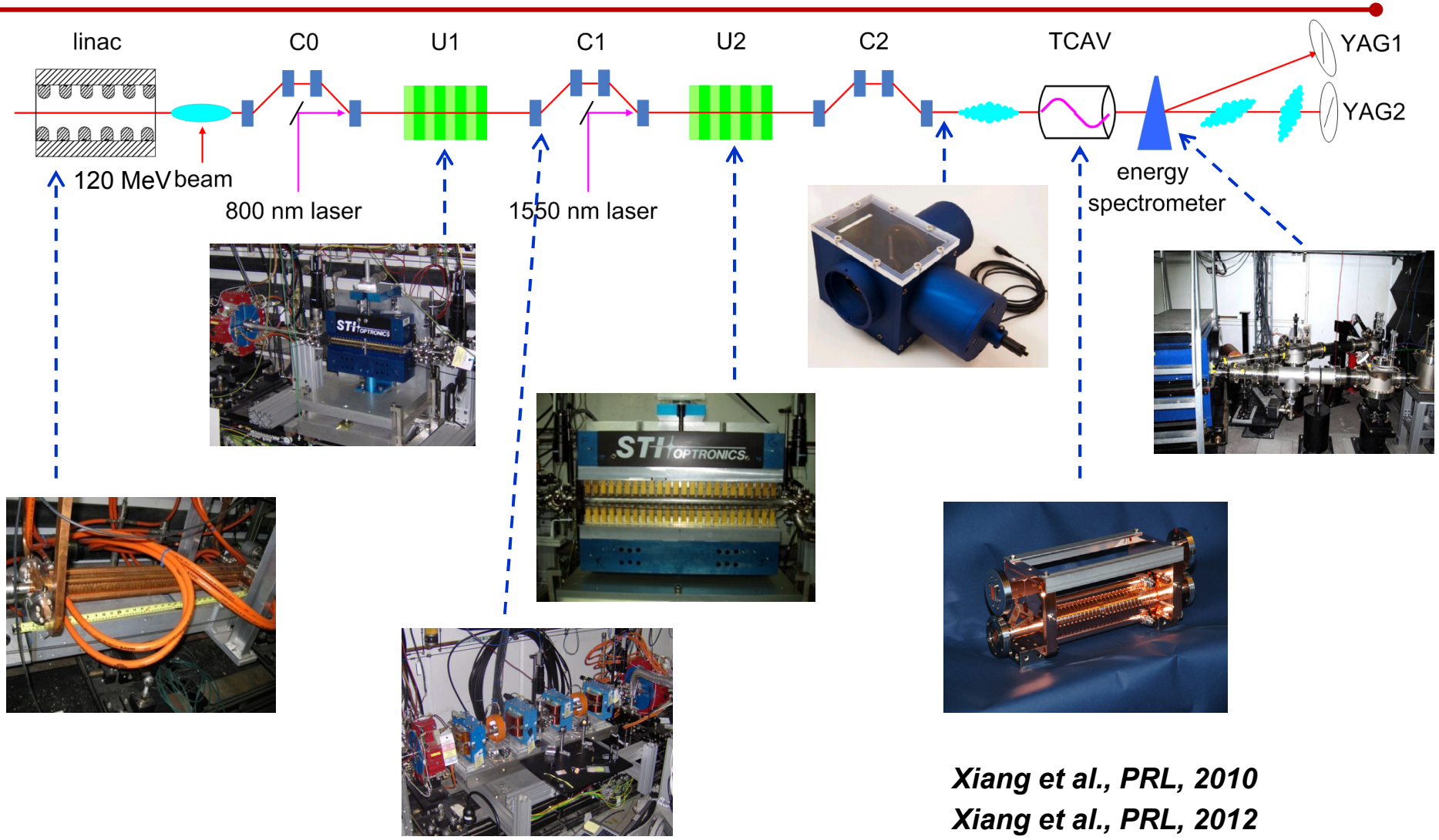
+

Laser2: 780 nm

THz: 60 μm

Xiang and Stupakov, PRST-AB, 2009

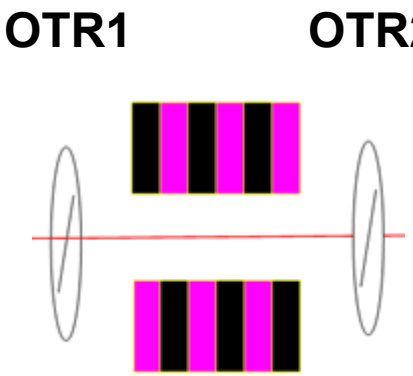
Test at SLAC's NLCTA



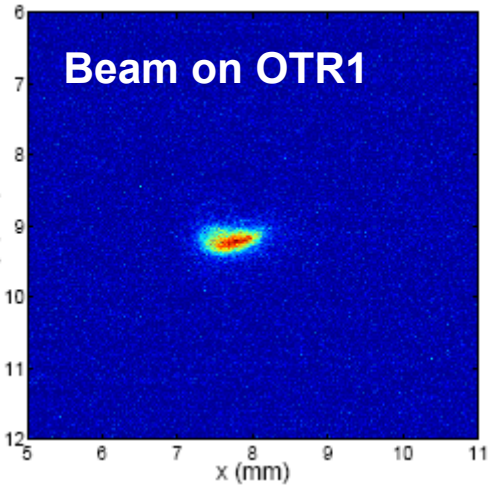
Xiang et al., PRL, 2010
Xiang et al., PRL, 2012

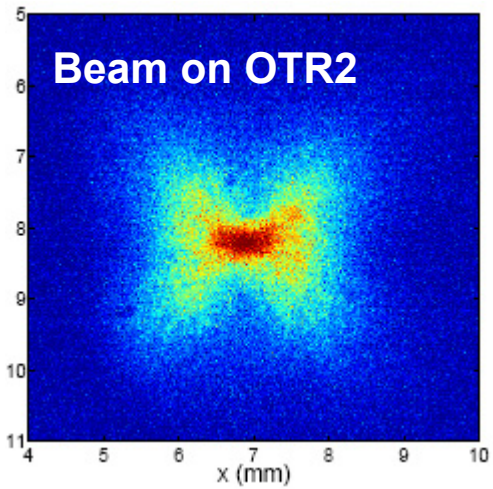
Test at SLAC's NLCTA

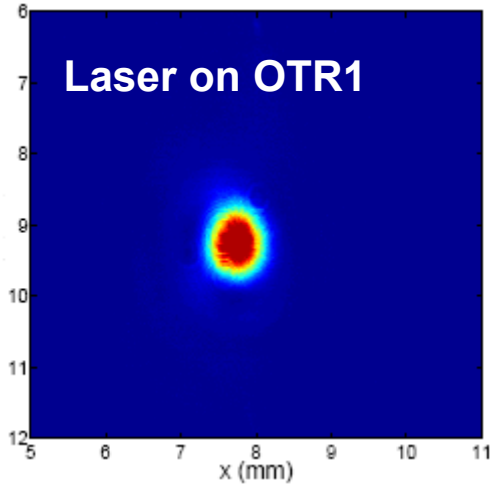
- Spatial overlap

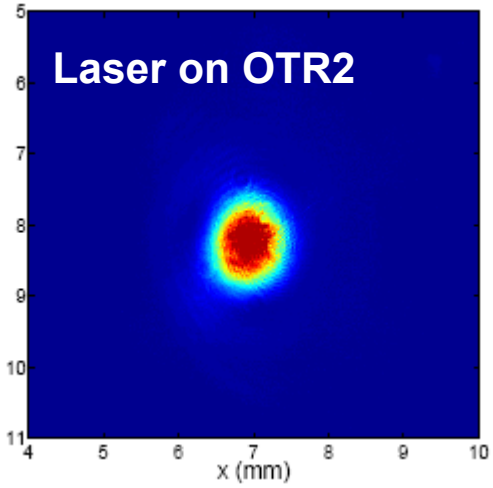


Beam-laser spatial overlap is achieved by steering the laser to the same position as the electron beam on the OTR screens upstream and downstream of the undulators









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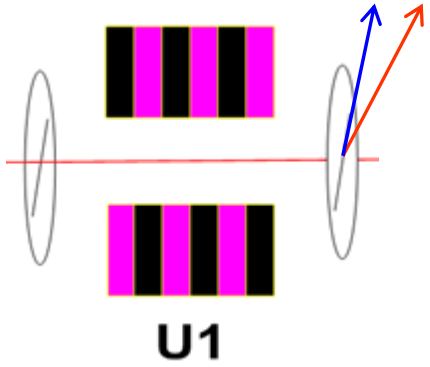
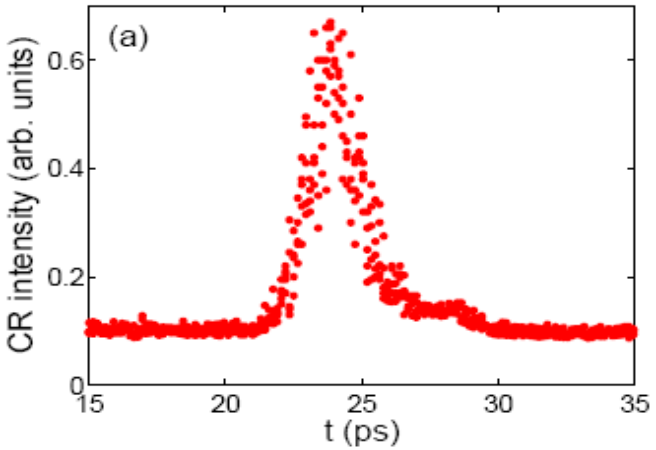
Test at SLAC's NLCTA

- Temporal overlap

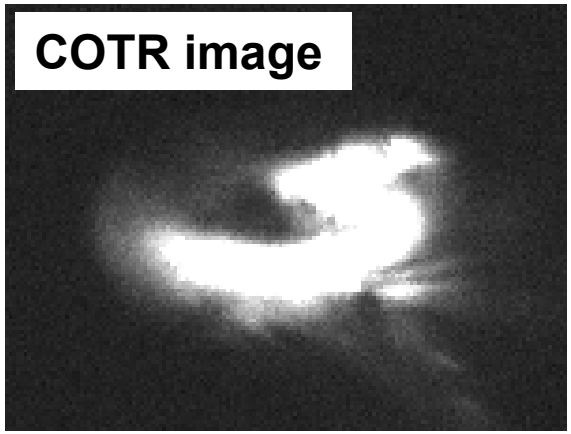
to a photodiode





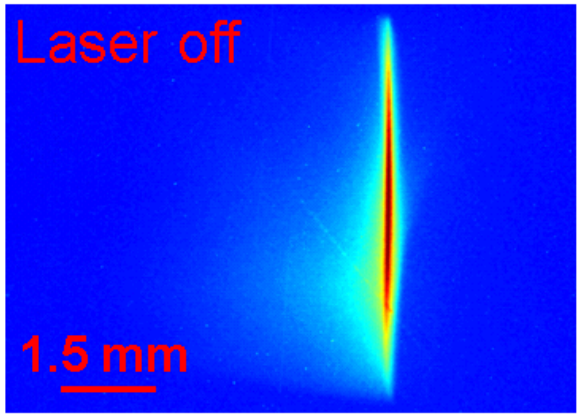
COTR signal vs laser timing

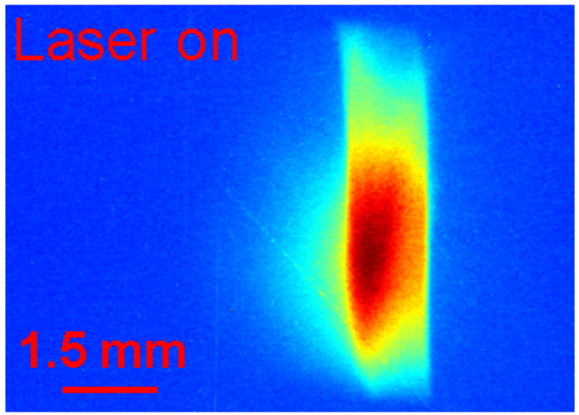
- The laser and undulator radiation are reflected out by the OTR screen and detected by a fast photodiode.
- Scan delay stage to finely adjust the laser timing until the COTR enhancement is observed.



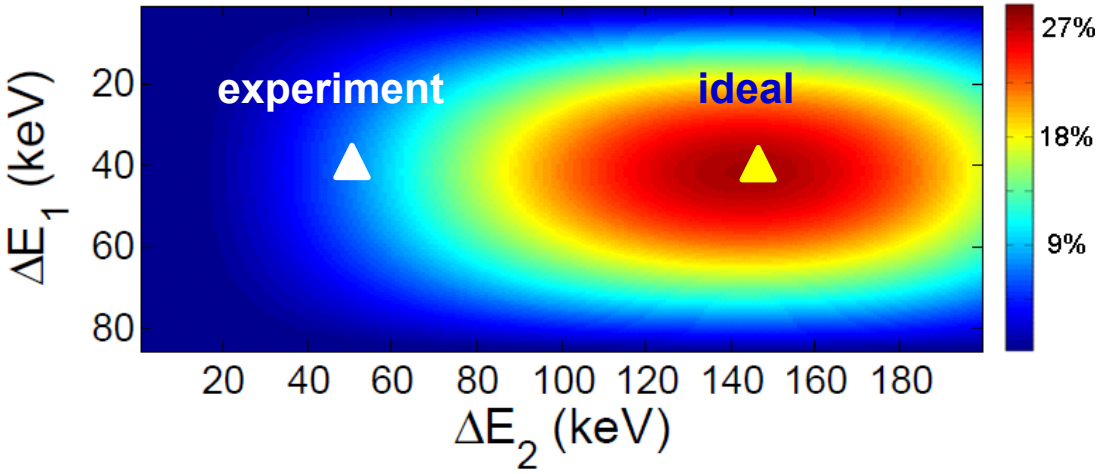
Test at SLAC's NLCTA

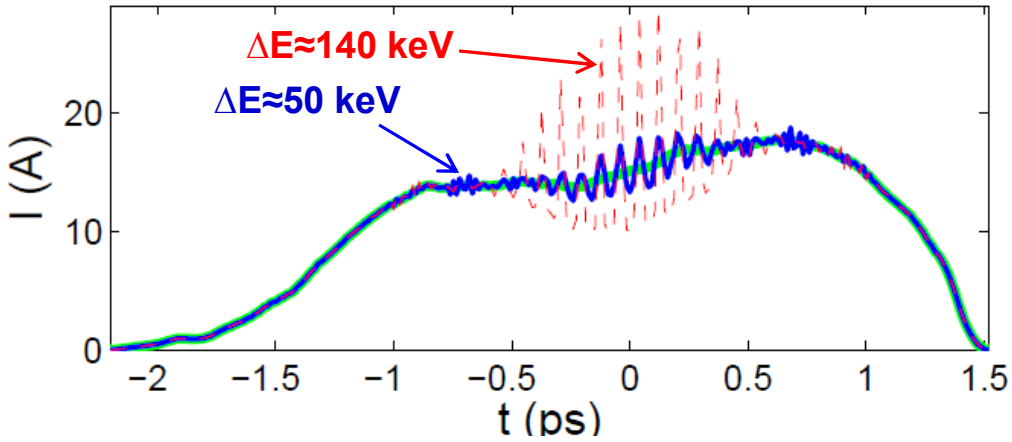
- Measure energy modulation





Beam energy distribution

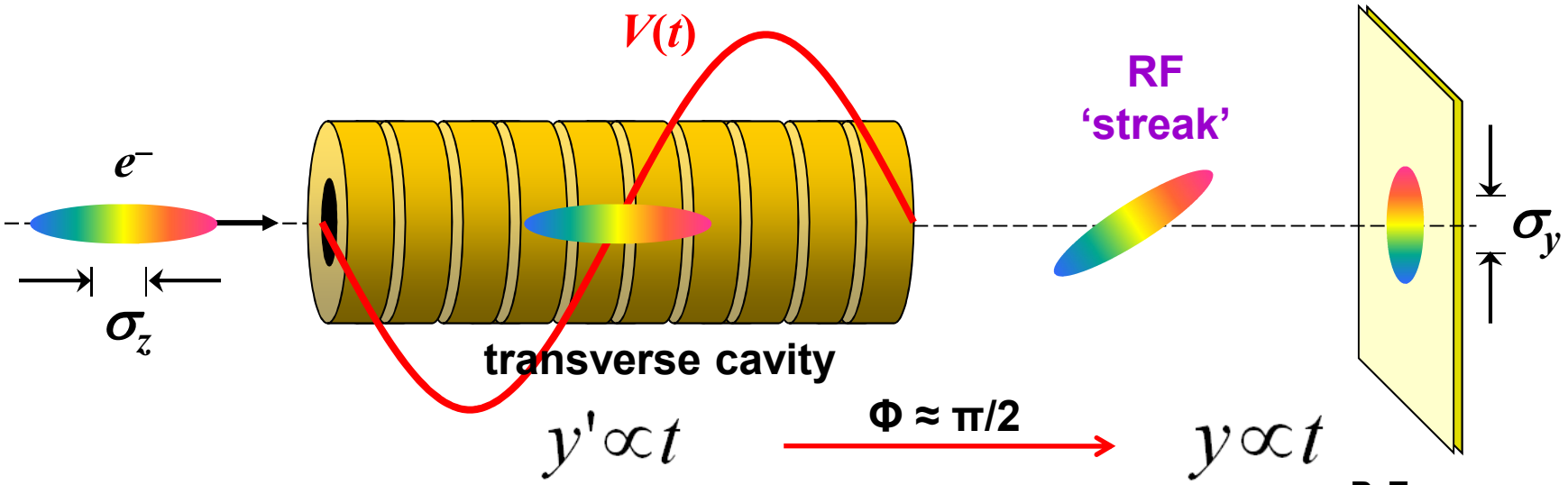




Simulated bunching and density distribution

Test at SLAC's NLCTA

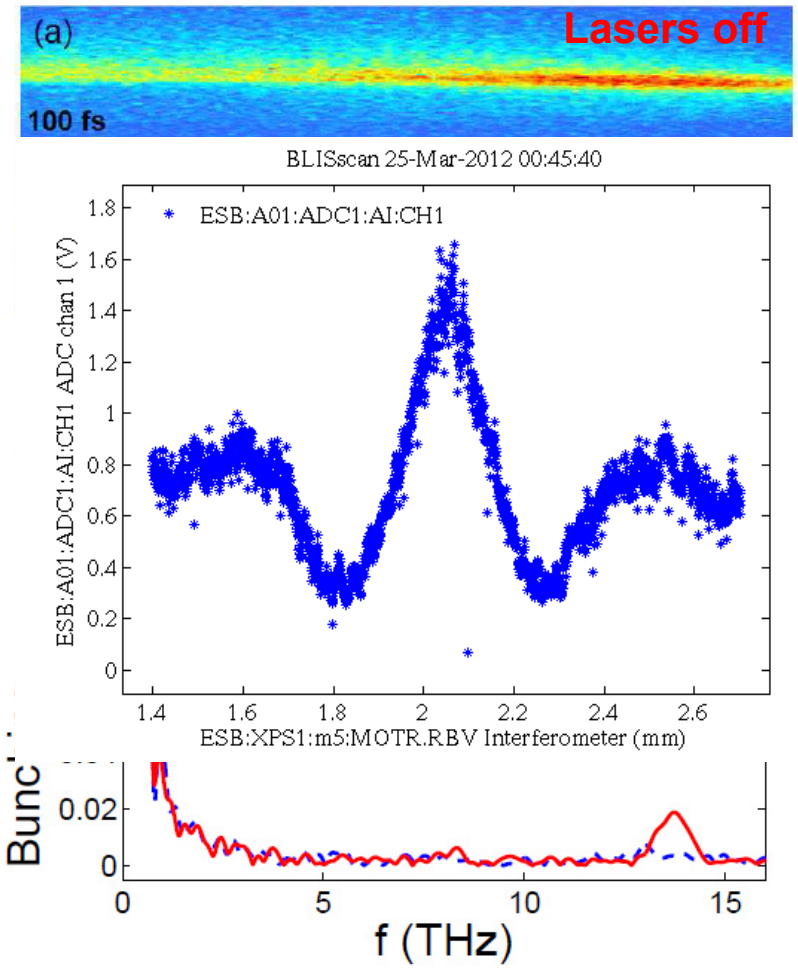
- **Measure THz structures with an rf transverse cavity**
  - **Deflecting cavity ~ crab cavity**
  - **Developed at SLAC in 1960's for particle separation**

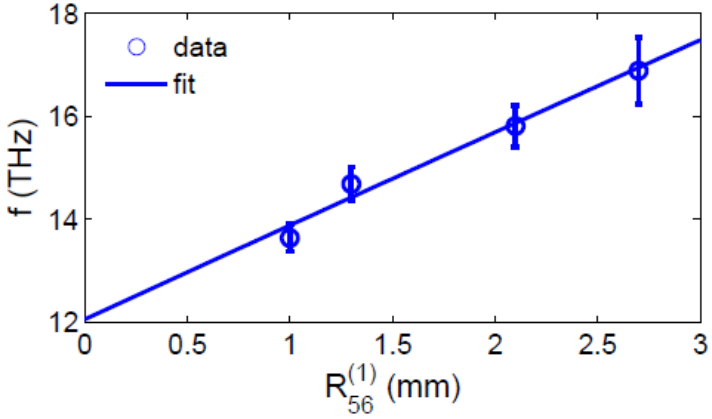


- Absolute measurement of bunch length and temporal profile
- 27-cell X-band TCAV at NLCTA provides ~30 fs resolution

Test at SLAC's NLCTA

- **Periodic THz structures in an e-beam**





Dunning et al., to-be-published in PRL, 2012

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Summary

- Growing interest in accelerator community to generate narrowband THz radiation
- Periodic THz structures generated in a relativistic e-beam
- In principle tunable in the whole THz range
- The next step is to measure narrow-band THz radiation

Many thanks to the Echo-7 team!

Thank you!