A System for Synchronizing Electron Bunches and Laser Pulses using a Photoconductive Antenna

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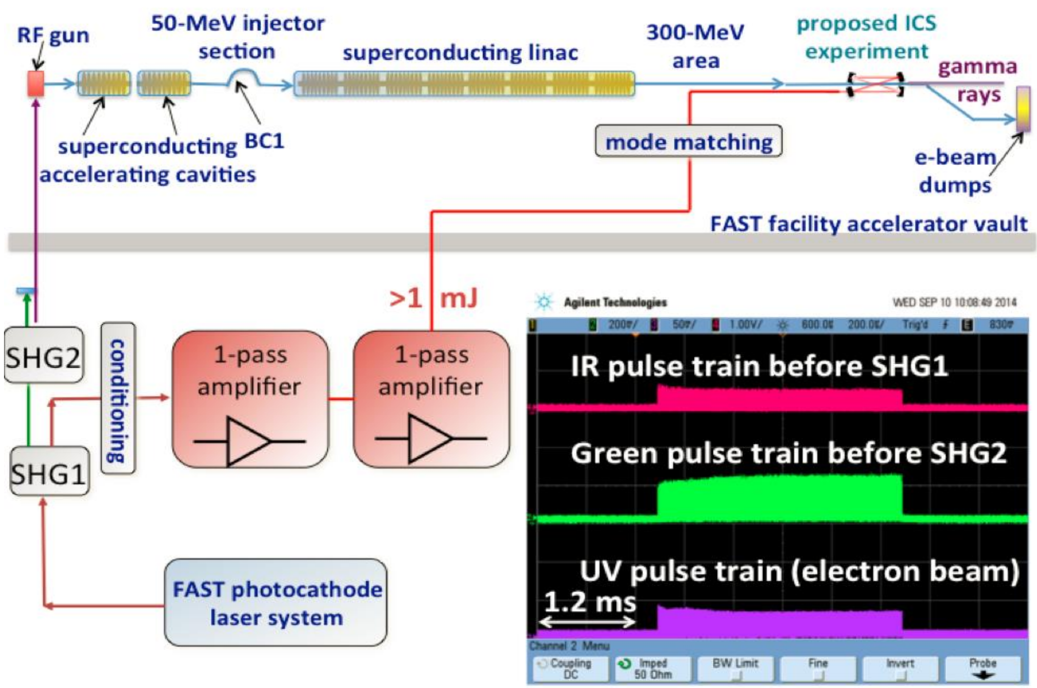
14 June, 2016

Outline

- Motivation
- Background: What is a photoconductive antenna and how does it work?
- Modern Devices: Large-area arrays and plasmonic enhancement
- An accelerator diagnostic application: electron and laser synchronization
- Present work status: experience with commercial device, upcoming/recent work w/ UCLA plasmonic device
- Future prospects

FAST-ICS Timing & Synchronization

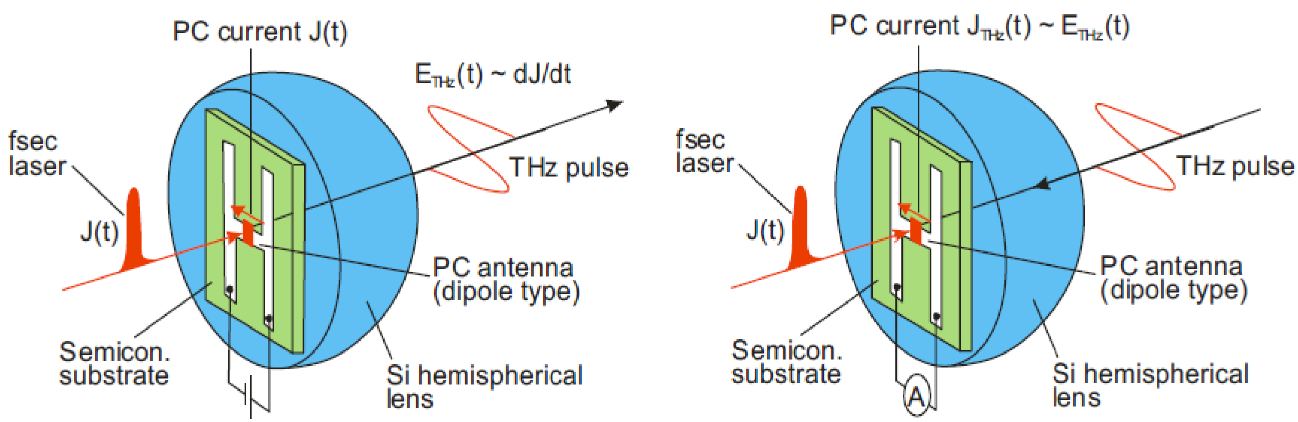
- Need synchronization of electron and laser pulses for high flux ICS
- Will use photodiode and BPM signals for ~ns level
- Propose to use photoconductive THz antenna for ps/sub ps

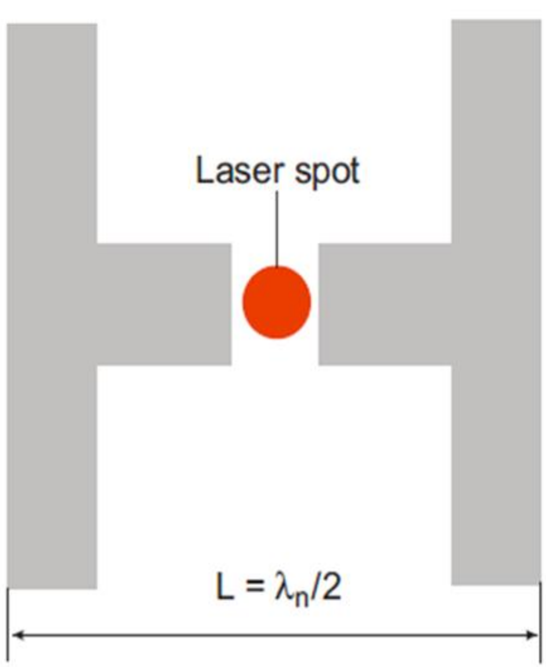


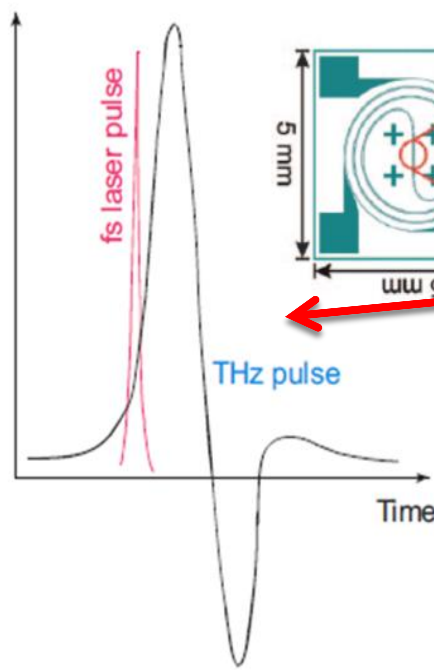
Parameter	Value
Bunch charge	5 nC
Macro-pulse length	1 ms
Macro-pulse rate	5 Hz
Micro-pulse rate	3 MHz (~ 330 ns)
Micro-pulse length	0.5 ps
Laser pulse length	3-4 ps (~ 1 ps compressed)

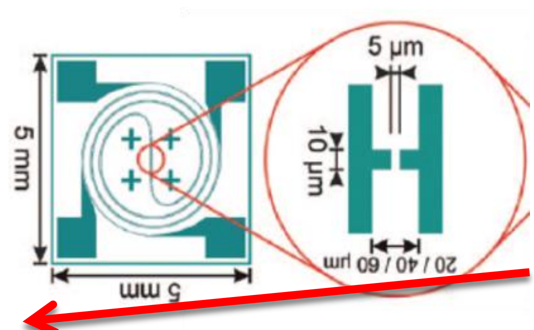
THz Photoconductive Antenna

- PCA uses antenna structure built on photoconductive substrate
- Pumped by fs laser
- DC bias to produce THz
- Measure antenna current to detect THz





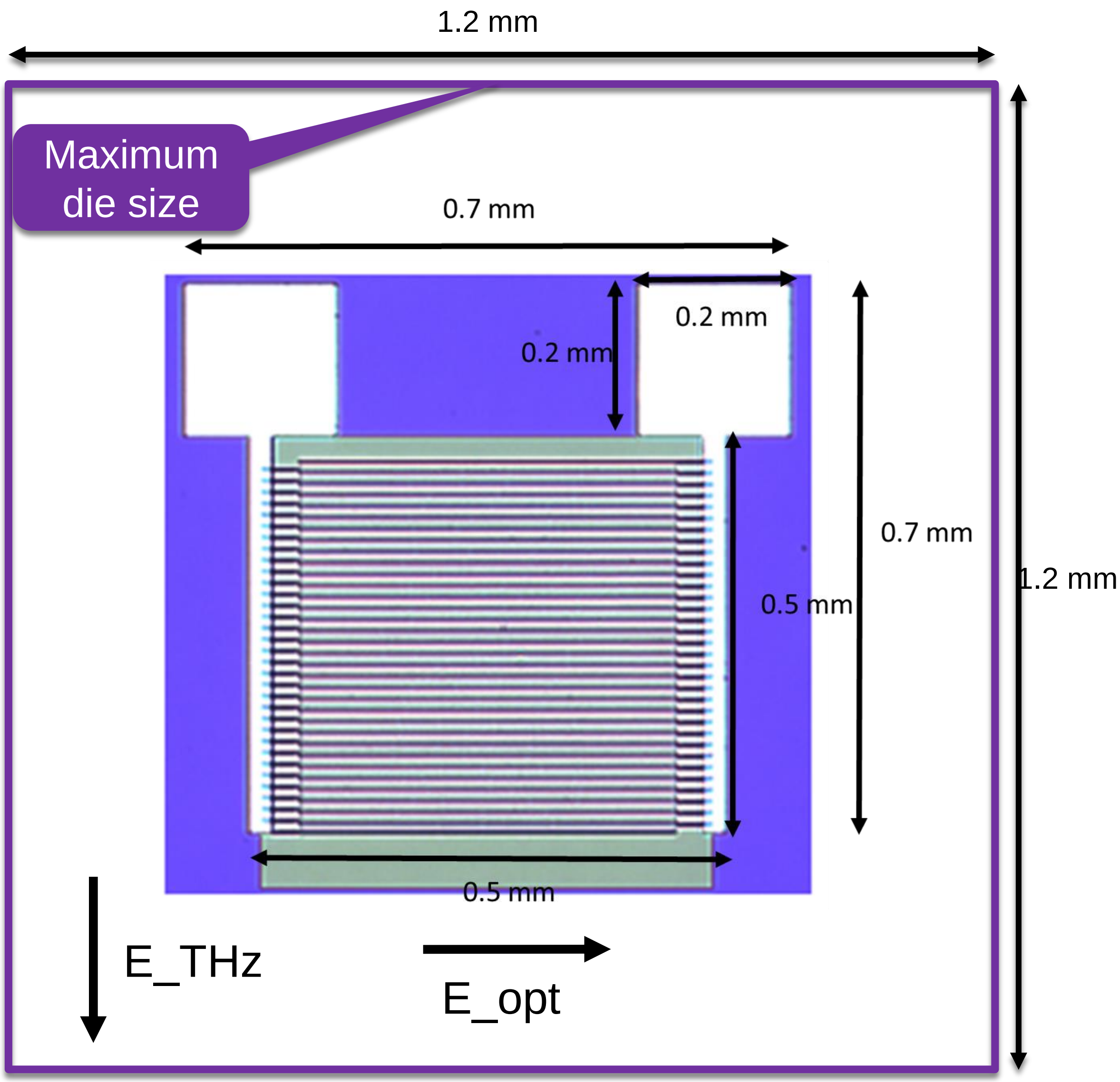




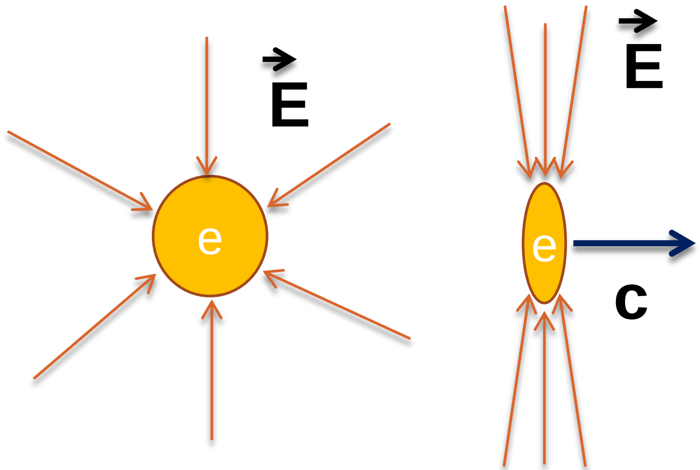
Vary the delay between laser and THz pulse to measure electric field amplitude

Recently developed UCLA THz chips

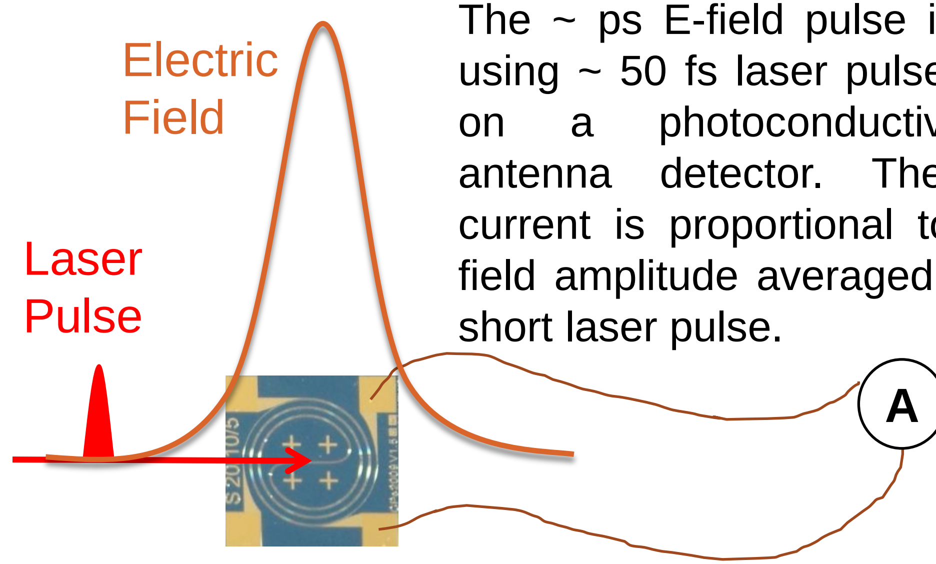
- Use surface plasmonic enhancement
  - Up to 50 x better detection per area than conventional PCA
- Detector active area:
  - 0.5 mm x 0.5 mm
- Individual dies:
  - < 1.2 mm x 1.2 mm
- Electrical contacts:
  - 0.2 mm x 0.2 mm
  - 0.7 mm between outer edges
- Input polarizations:
  - Vertical for the THz
  - Horizontal for the laser



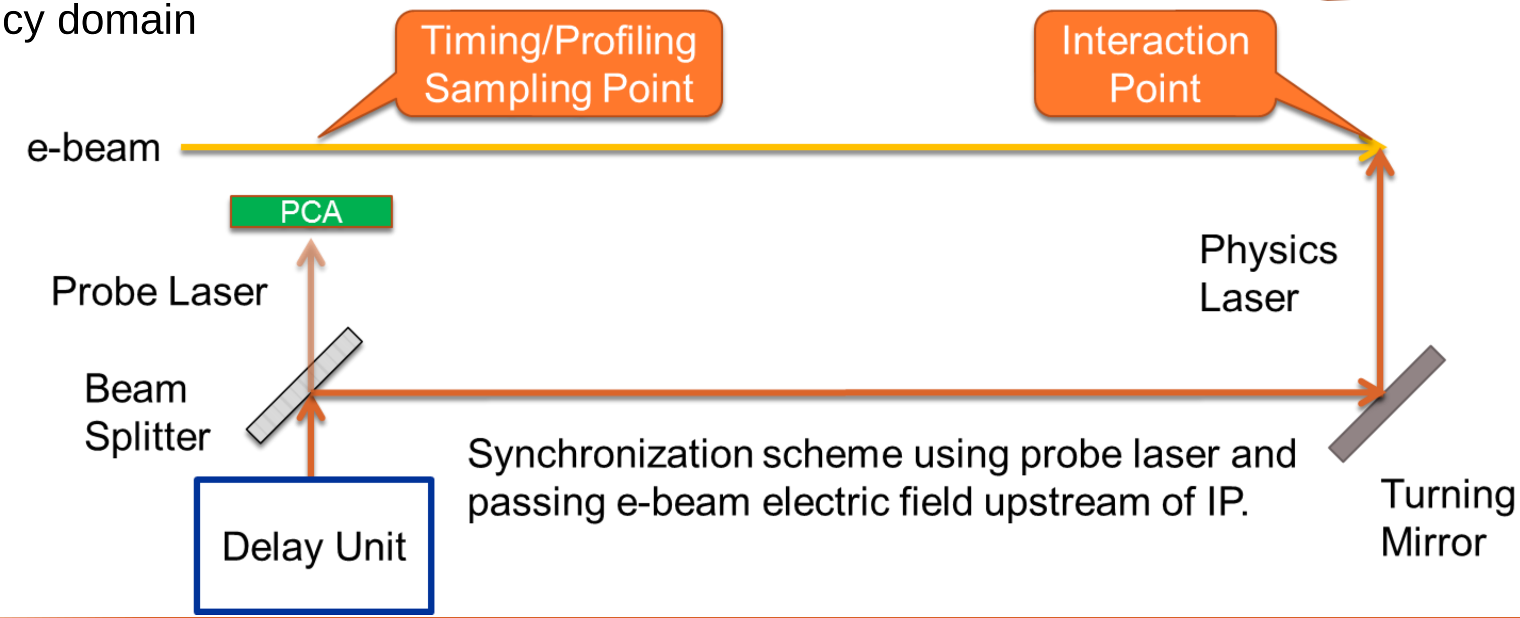
Timing of Relativistic Pulsed E-beams



Passing field of ps long relativistic electron beam in lab frame is THz in frequency domain



The ~ ps E-field pulse is probed using ~ 50 fs laser pulse incident on a photoconductive THz antenna detector. The output current is proportional to electric field amplitude averaged over the short laser pulse.

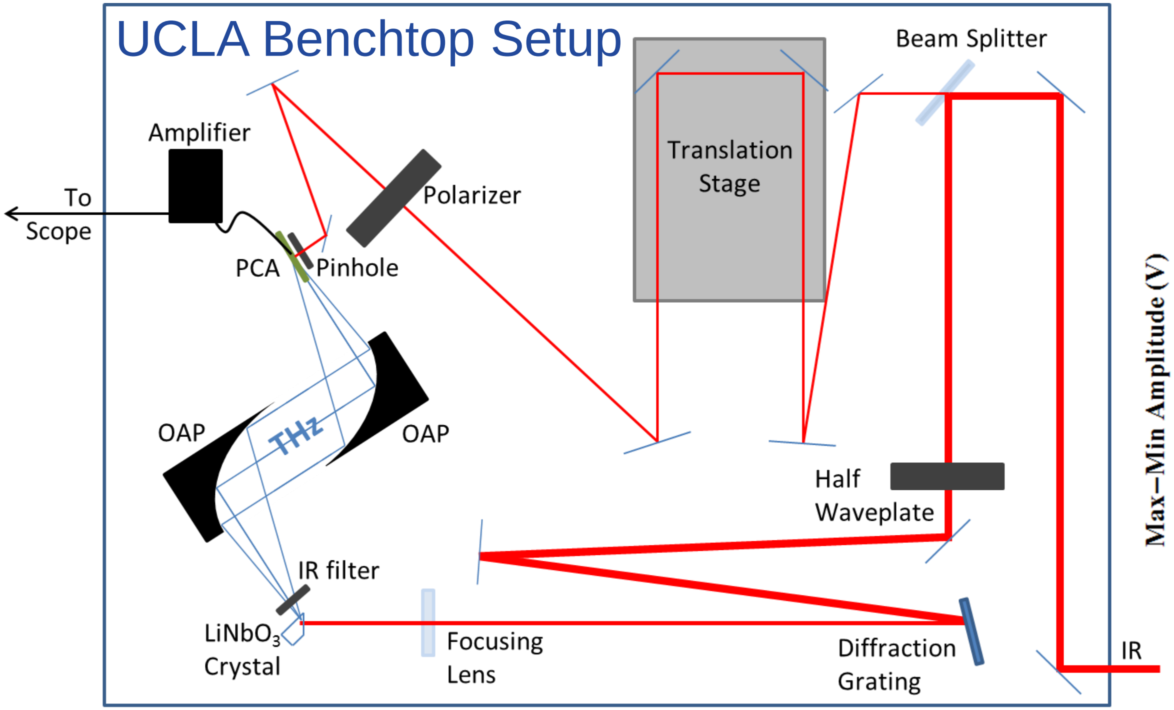


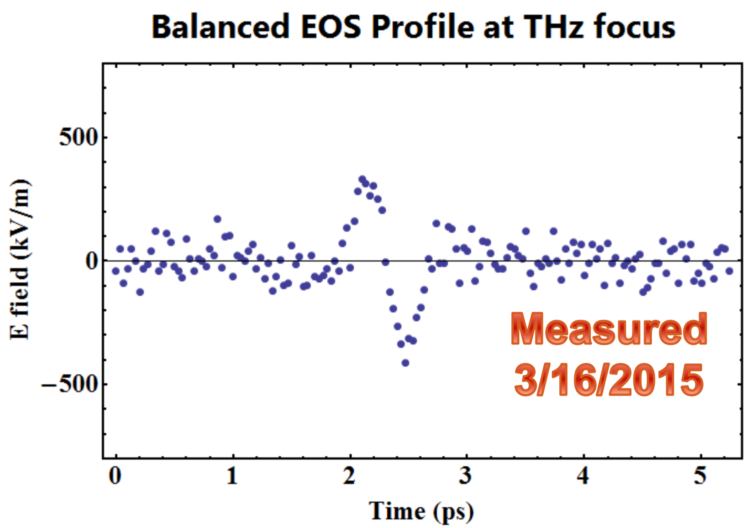
Synchronization scheme using probe laser and passing e-beam electric field upstream of IP.

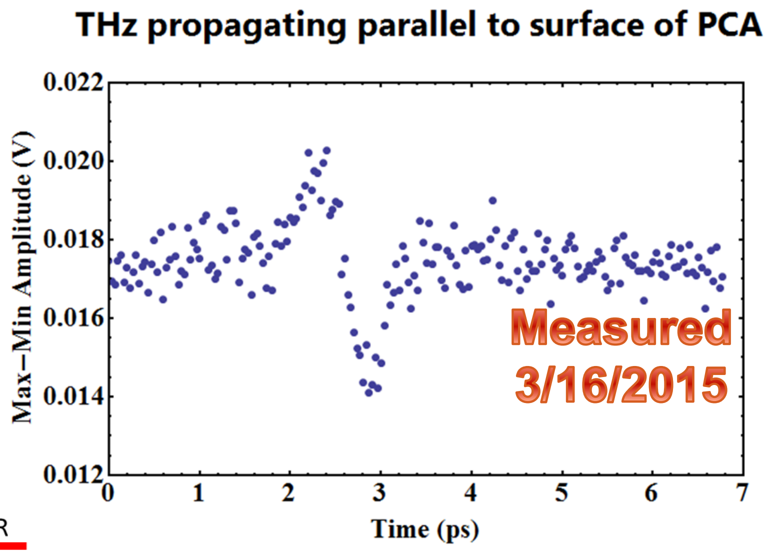
Time-Resolved E-Field Measurements

radiabeam TECHNOLOGIES

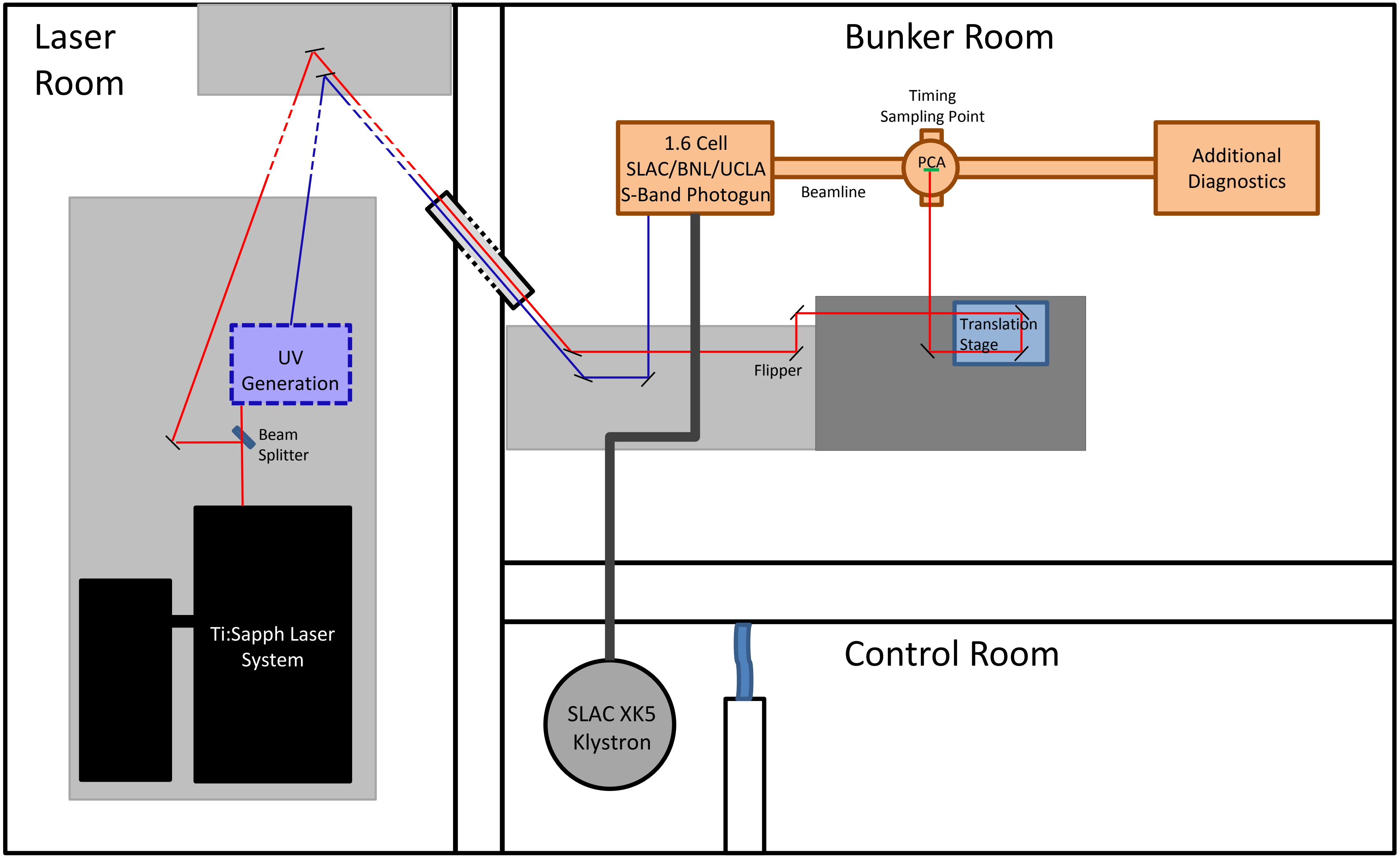
- The PCA timing has been benchmarked against an electrooptical sampling method at UCLA.
- The probe beam is masked down to 50 um using a slit illuminated by 6 mm diameter laser
- Probe average power is < 0.5 mW at 1 kHz
- THz peak-to-peak timing is 0.6 ps using PCA
- THz peak-to-peak timing is 0.4 ps using EOS
- Profiles agree well





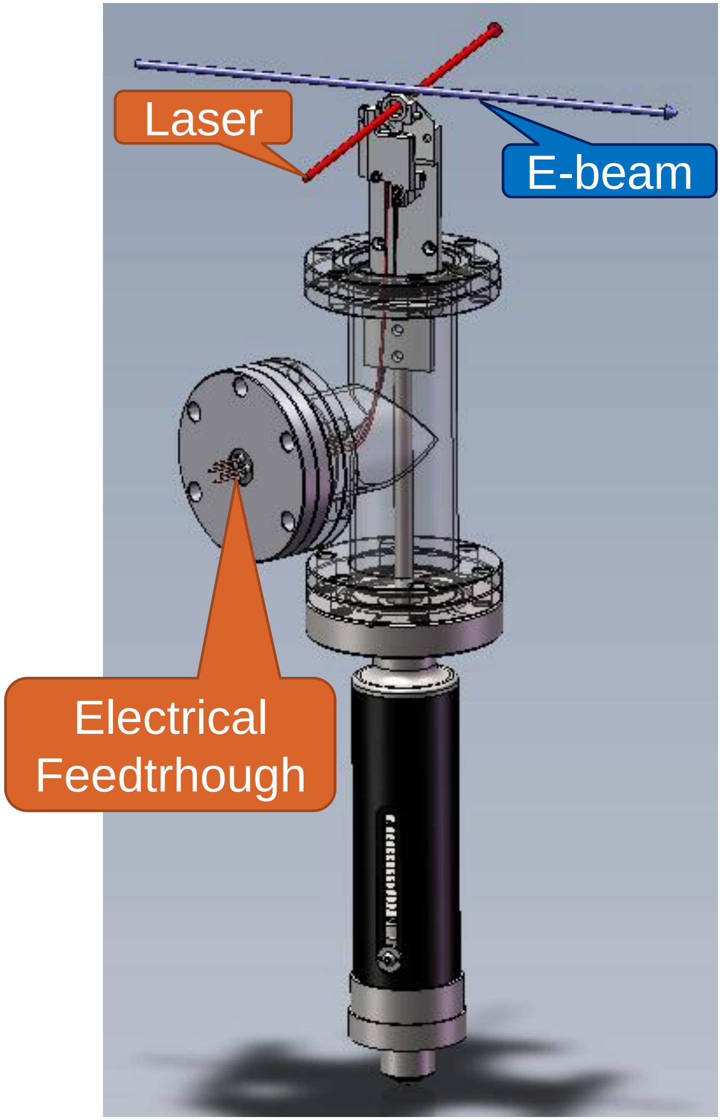


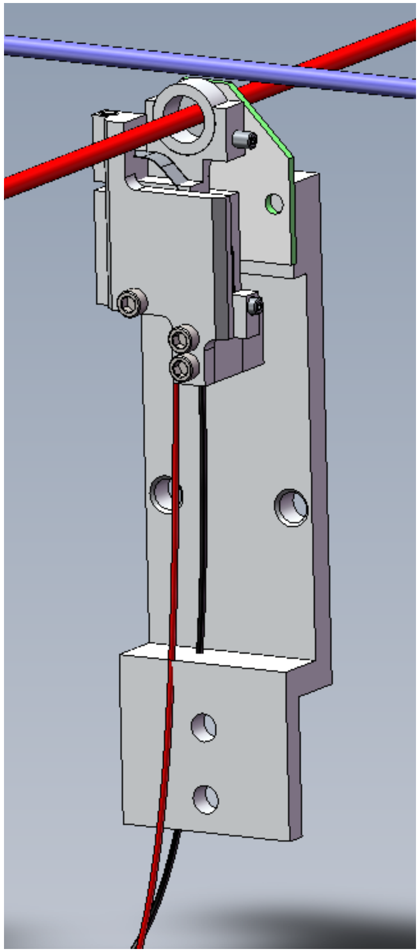
Pegasus Laboratory Beam Test



Pegasus Beam 1st Test Assembly

Internal Components

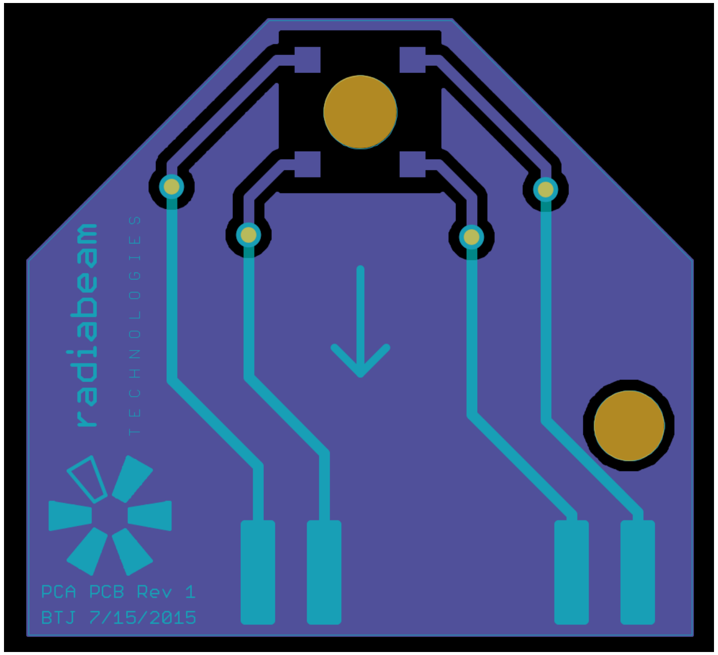




New PCB to carry TERA-8 chip →

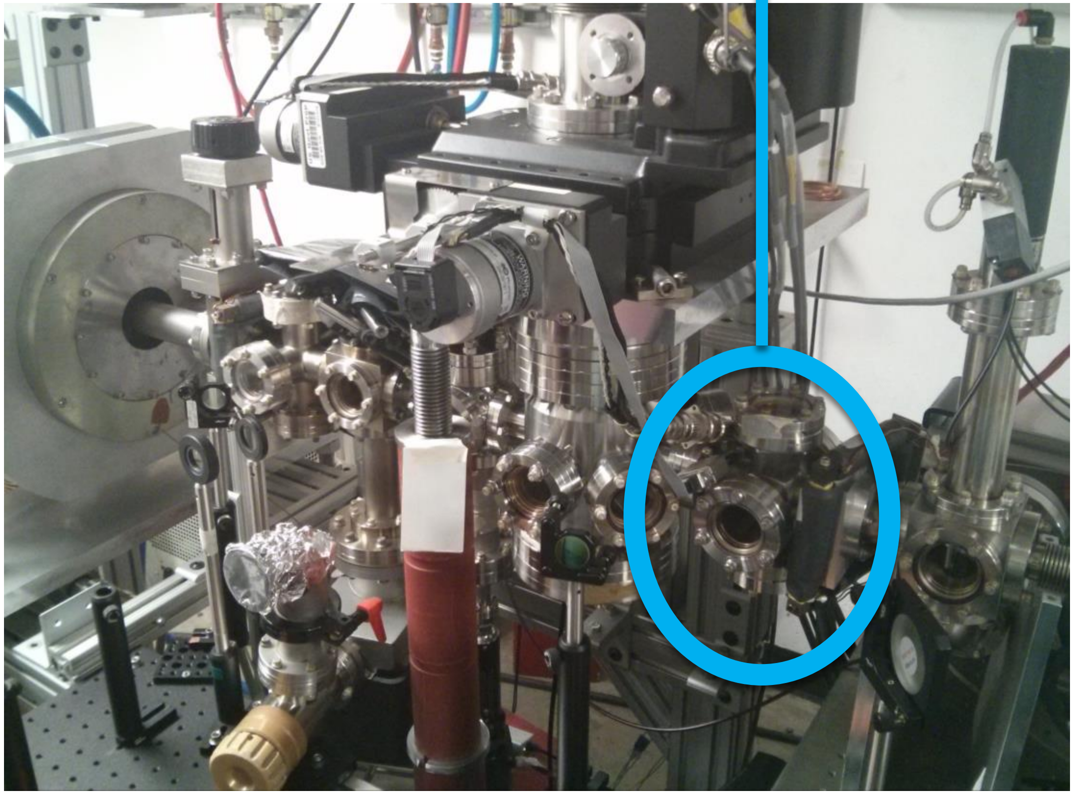
PCB Clamp Assembly w/ pinhole ←

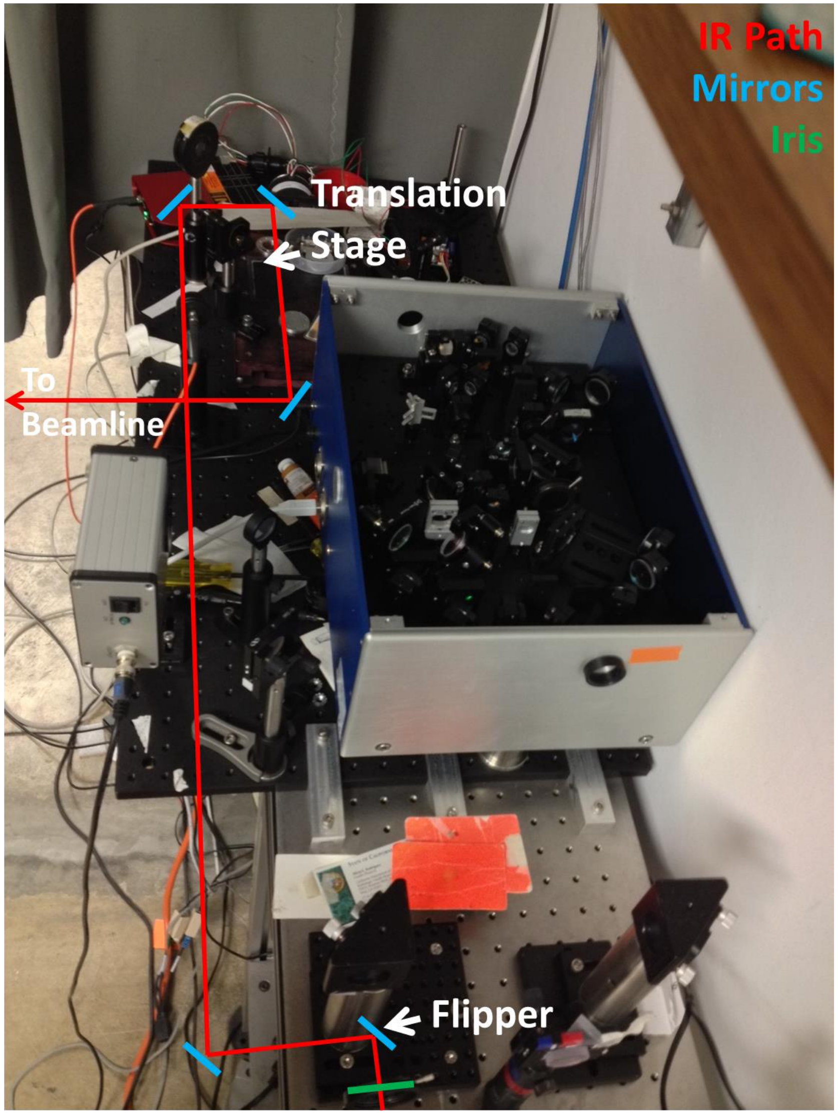
← 1 inch →



In-Tunnel Hardware

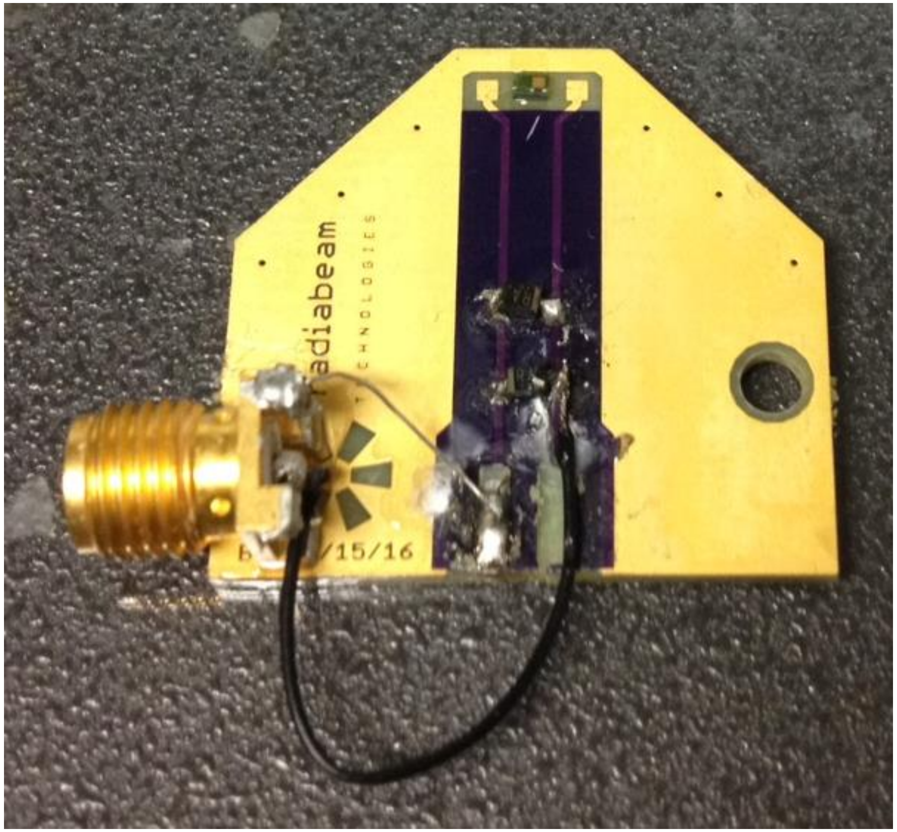
- Locate experiment in 6-way cross
- Have plan for probe laser, timing already close





Mounting of Large Area PCA

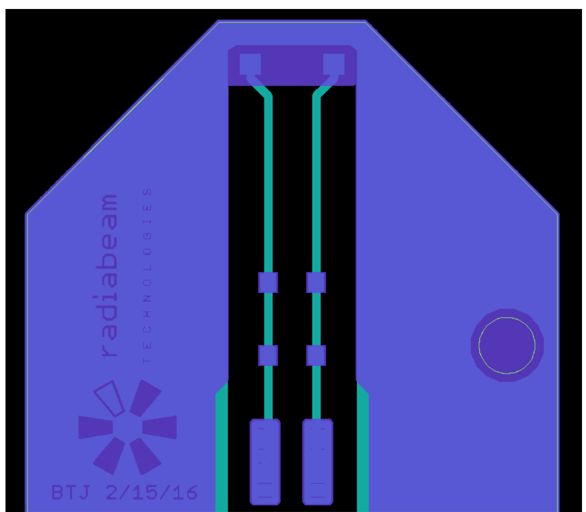
- The PCB is used for bench test and practice assembly of chip and board
- The pad sizes on the RBT board are 1 mm square for reference
- This version had connector issues…



RadiaBeam PCB for PCA chip.
Top-side (left) and bottom-side (right)

Improvements for Next Beam Test

- Use the plasmonic device
- Have improved PCB design with ESD protection diodes
- Use triaxial shielded cable
- Can use large laser spot size
- Try to beat the tunnel RF noise and detect ~ pC at UCLA
- FAST has nC!



Conclusion

- We are working to develop hardware for beam timing and synchronization based on large area photoconductive antennas
- We have been unsuccessful using commercially available devices for this application
- We continue to test new devices with benchtop and beam based THz sources
- We plan to test using higher charge beams at FAST this fall

Recent OTR Measurements

MEASUREMENT OF TEMPORAL ELECTRIC FIELD OF ELECTRON BUNCH USING PHOTOCONDUCTIVE ANTENNA

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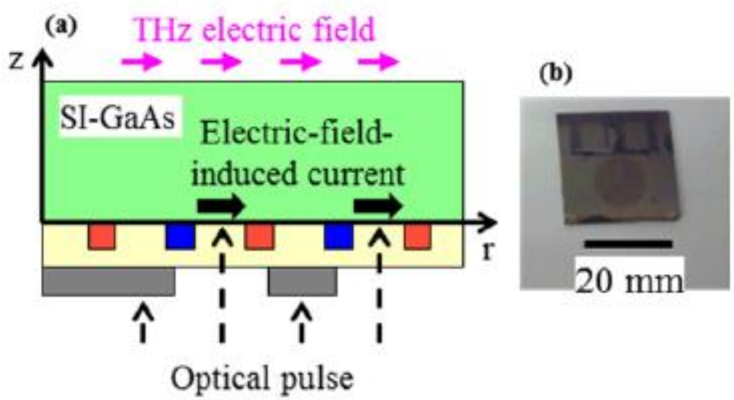


Figure 2: (a) Diagram of simplified azimuthal cross section of the large-aperture PCA (red and blue: conducting electrodes, yellow: insulating layer, gray: photomask). (b) Picture of a PCA.

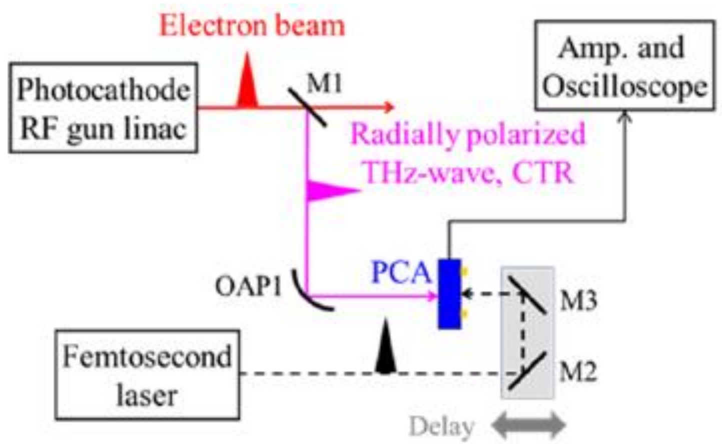
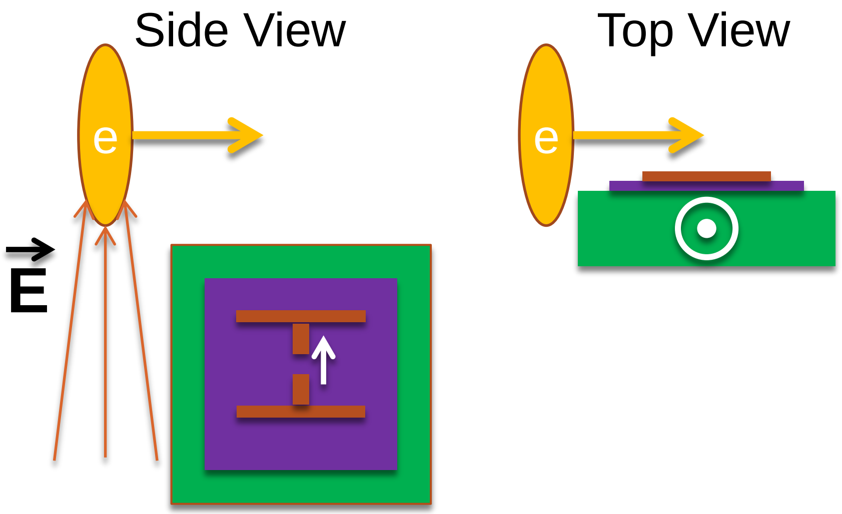


Figure 3: Schematic diagram of time-domain measurement of CTR using the PCA.

Beam THz Polarization Issues

- Electric field of the beam is "pancake" shape with nearly *radial* polarization wrt to beam's velocity vector.
- Electric field of the optical rectification THz source is *vertical* wrt to the pulse propagation vector.
- The antenna in the PCA is, like all antennas, polarization sensitive
- So, we need the antenna to be oriented correctly – two options shown at right
- "facing" orientation is limited by fiber-coupled assembly, near-axis free space laser coupling more difficult
- "sideways" orientation is possible with old and new chip assemblies



- Above: "sideways" orientation
- Below: "facing" orientation