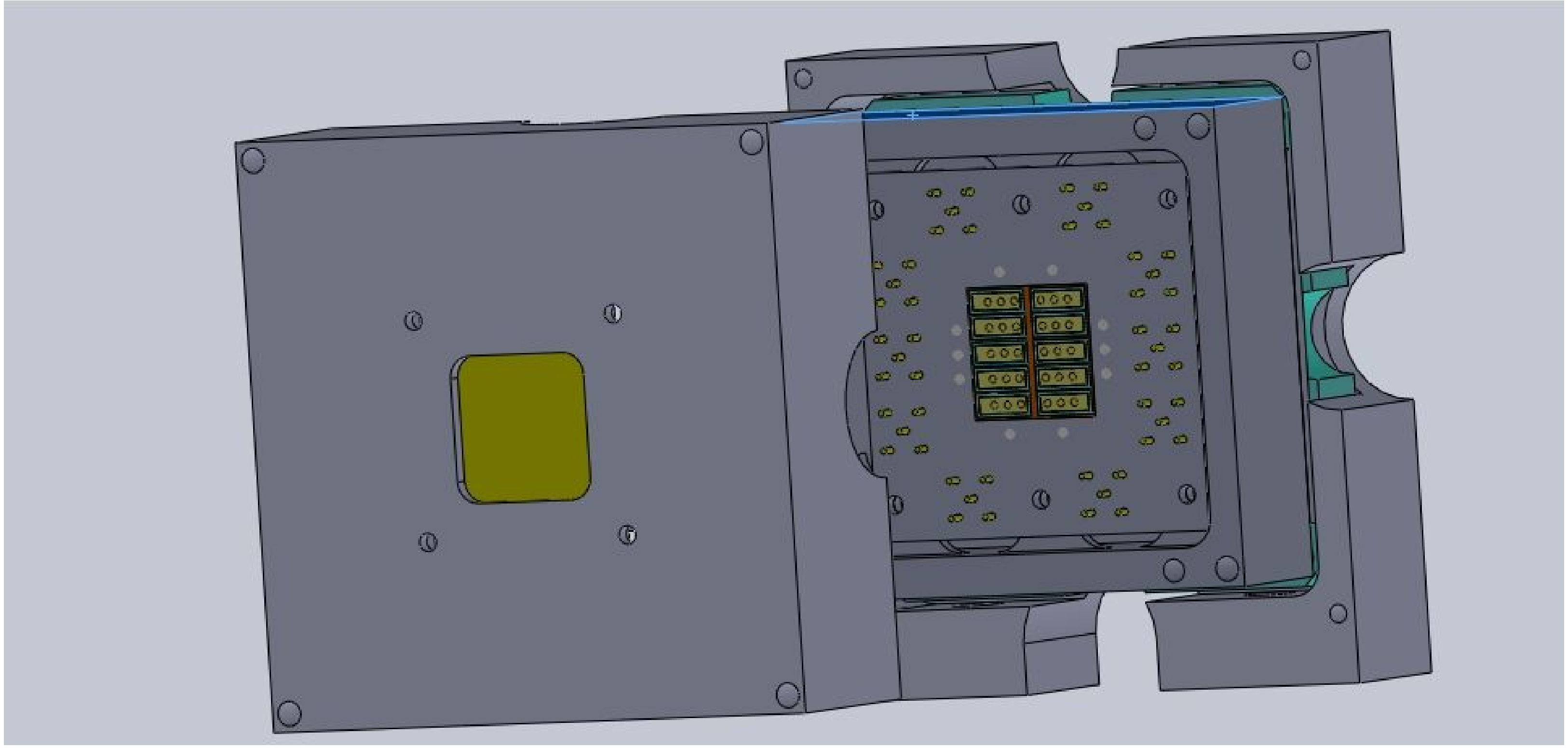
A pCVD diamond detector for a slowed down ion beam in high energy laser environment

TECHNISCHE UNIVERSITÄT DARMSTADT

1st ADAMAS Workshop - December 18th 2012 - Alexander Knetsch



GSI HELMHOLTZ GEMEINSCHAFT

Outline

1. Scientific Motivation
   - Energy loss measurements in new velocity regime

2. Challenges

   - Low ion beam energy: Polarization
   - Wide spread ion beam
   - Energy resolution
   - X-ray saturation

3. Solutions

4. Results

Motivation

- **We detect particle bunches, no single particles**
  - **At least several hundred ions each 9.24 ns or 27.6 ns**
  - **Each ion has an energy of 3.6 MeV/u**

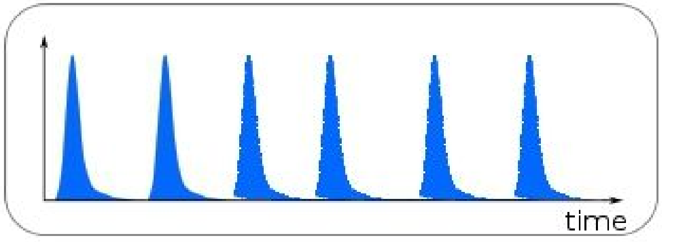
- **High radiation hardness :**
  - A few thousand ions per bunch.

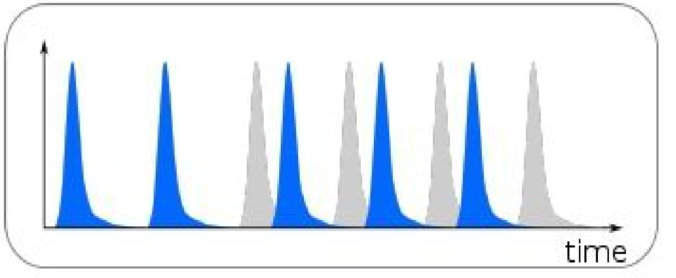
- **High time resolution :**
  - Micro bunch duration *2-3 ns*
  - Time resolution has to be significantly below *1 ns*

- **Fast detector :**
  - Micro bunch frequency *9.24 ns or 27.6 ns*
  - High repetition rate, time constant of few ns

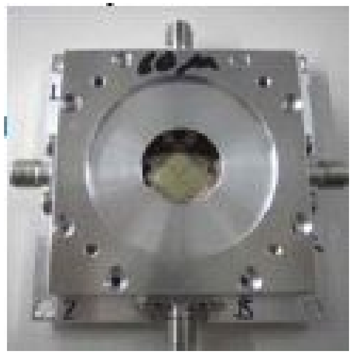
+ Possible use at room temperature (low noise)

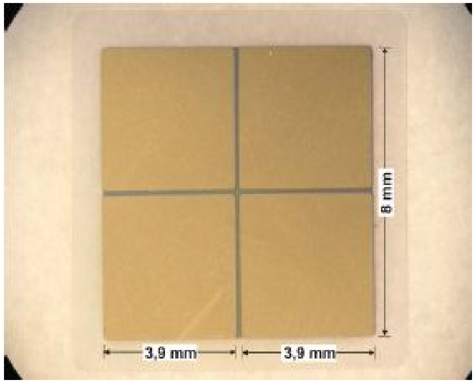
CVD diamond detectors are ideal for our experiments





Overview of our CVD diamond detectors



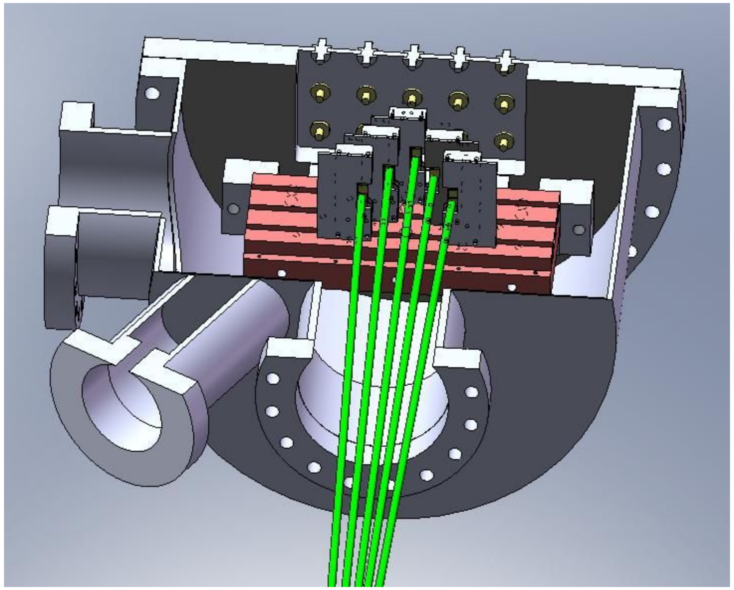


<u>First application (2006)</u>

Stop detectors for energy loss measurement

Surface 8*8 mm²

Thickness 20 µm



E= 3.6 - 4.8 Mev/u

<u>Next development (2009)</u>

Charge state spectrometer for energy loss <u>and</u> charge state distribution measurement <u>simultaneously</u>

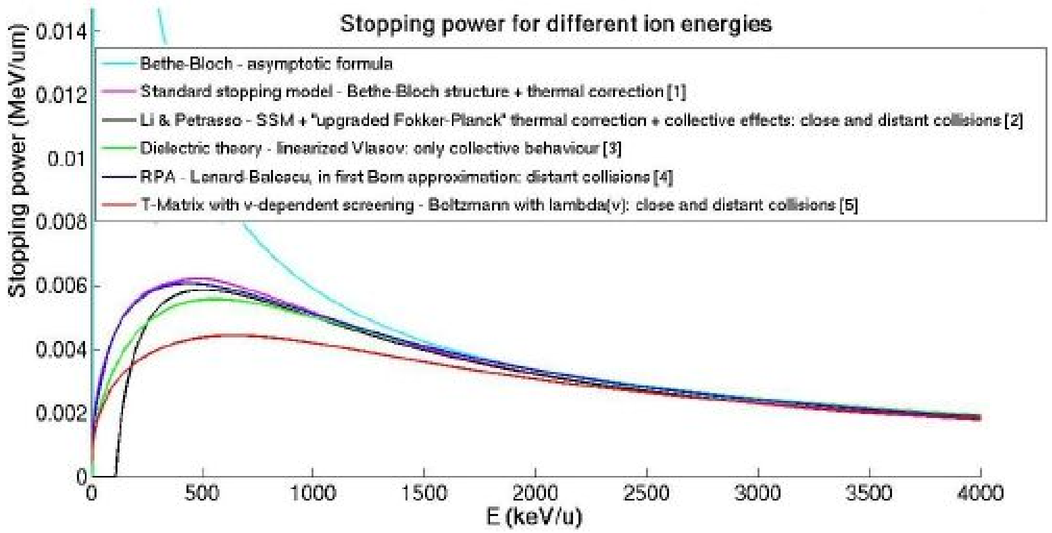
5 diamonds for 5 charge states

Surface 20*7 mm²

Thickness 20 µm

W.Cayzac et al.

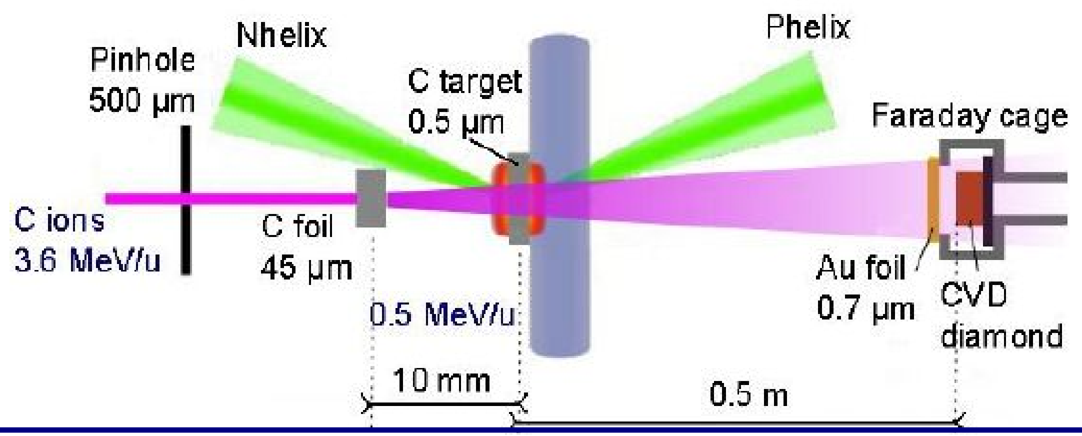
Newest Experiment



Stopping power for T=200eV $n_e=10^{21}cm^{-3}$

- Stopping power theories show vast discrepancies in the region of maximum stopping power ($v_{Ion} = v_{th}$)
- Detector needs ΔE<200keV.
- Ion beam needs to be slowed down.

Experimental setup

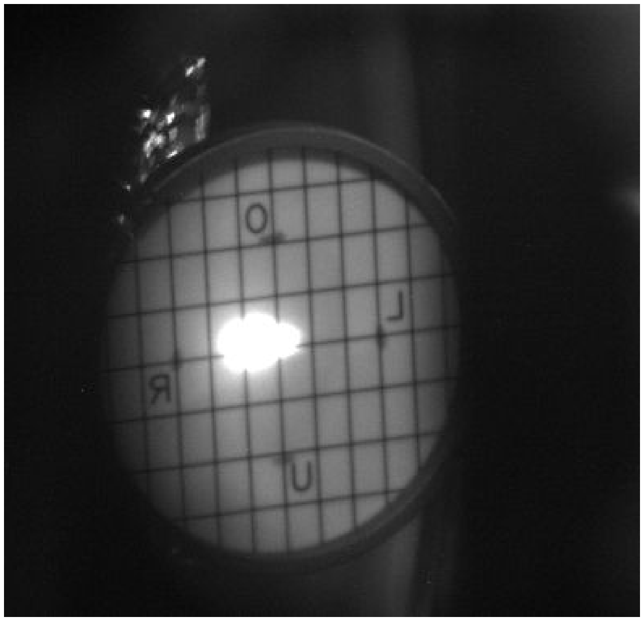


- 45 m C-foil slowes down and scatters ion beam.
- Phelix and Nhelix Laser Pulse.
- Laser parameters:
  - t=7ns, E=30J
  - Phelix: 527nm Nhelix: 532nm

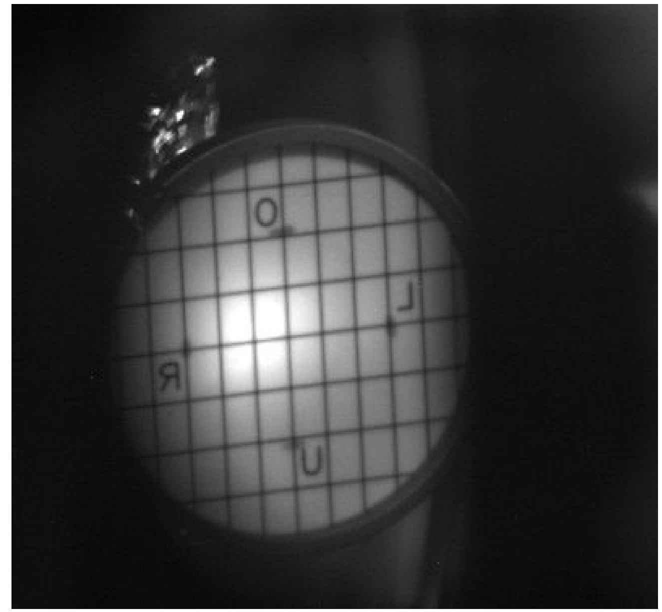
Plasma parameters:

- T=200eV n_e=**10**^{21} cm^{-3}

Challenge:
Wide spread ion beam



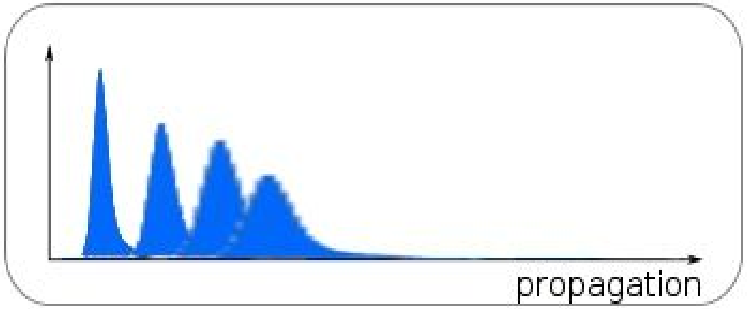
Scintillator in front of detector w/o decelerating foil



Scintillator in front of detector <u>with</u> decelerating foil

- Relatively small amount of detectable ions

Challenge: Energy resolution

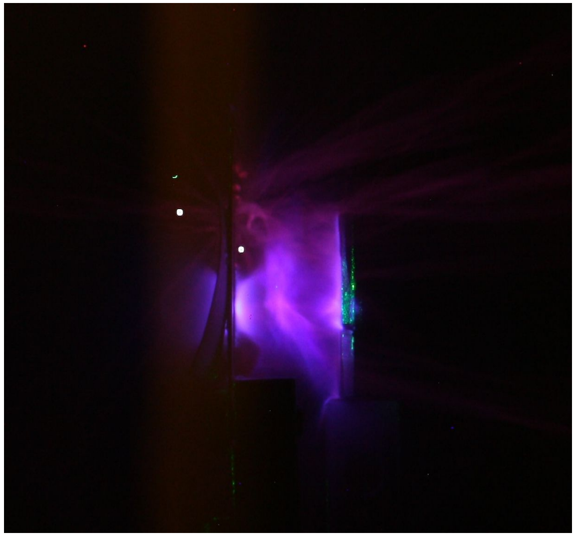


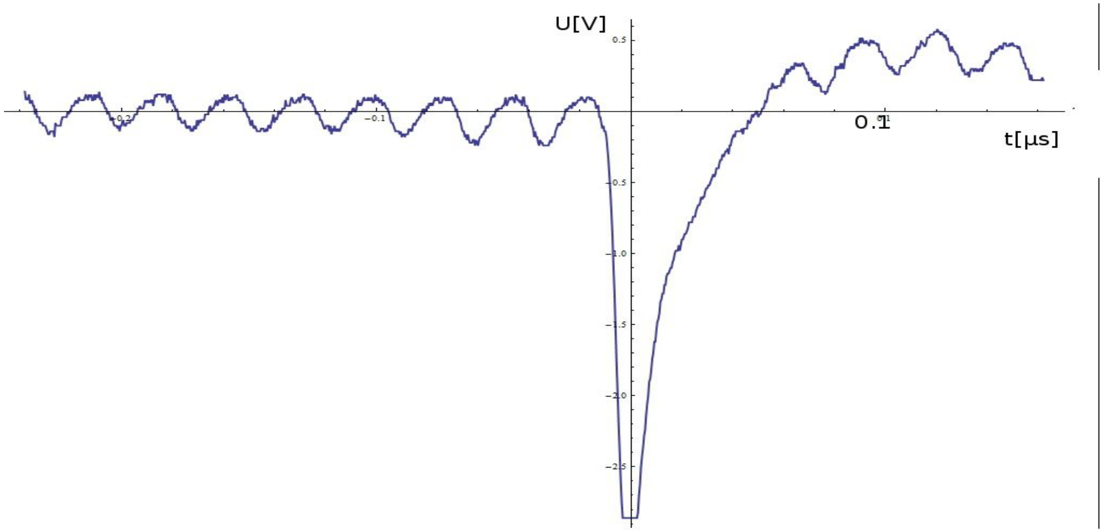
Broadening of bunches give maximum distance for detector (ΔE<60keV)
- 70 cm @ 108MHz
- 4 m @ 36MHz

Higher time of flight leads to better energy resolution

Ions lose up to 10% of their energy in the plasma.
→ a distance of 50cm is possible

Challenge:
High energy lasers environment





Saturation times due to
- Direct x-ray exposure from plasma
- Indirect exposure by EMP

Maximum saturation time: **50 ns**

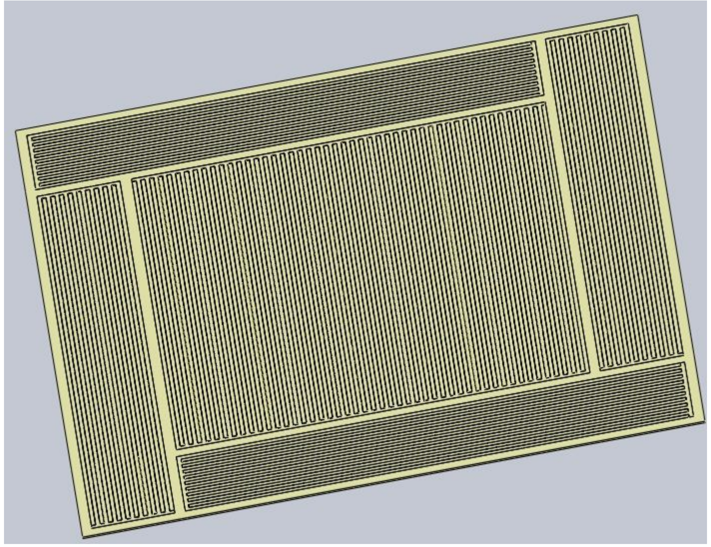
Challenge: polarisation

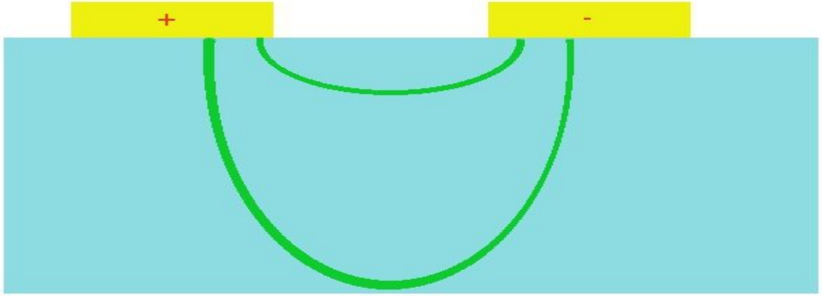
2-6 µm penetration depth

→Carriers are generated at the diamond surface

→**Risk of polarisation**

Interdigitated electrode structure





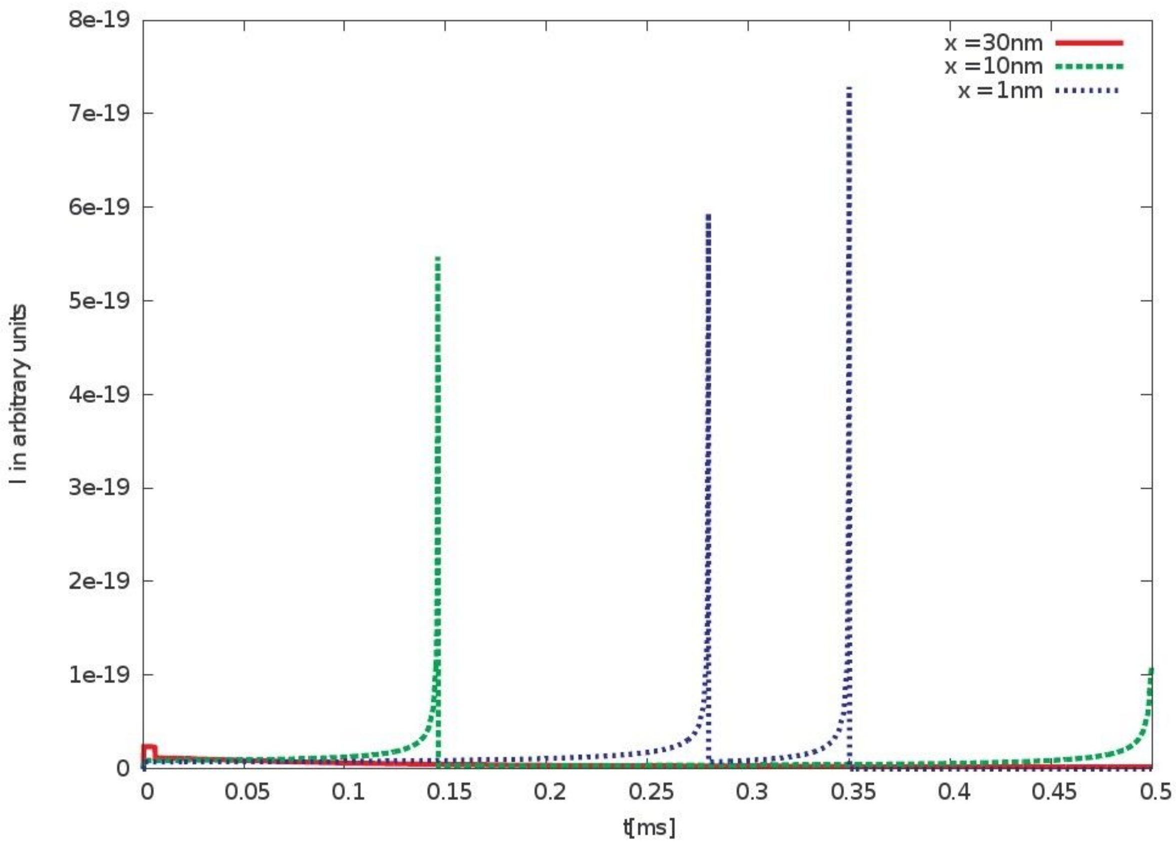
Draft of electron and hole trajectories in diamond

Idea:

An interdigitated electrode structure could be a fast detector for near-surface electron-hole pairs
→ less polarisation effects

→ Smaller Capacitance gives smaller time constants

Problem with interdigitated structure

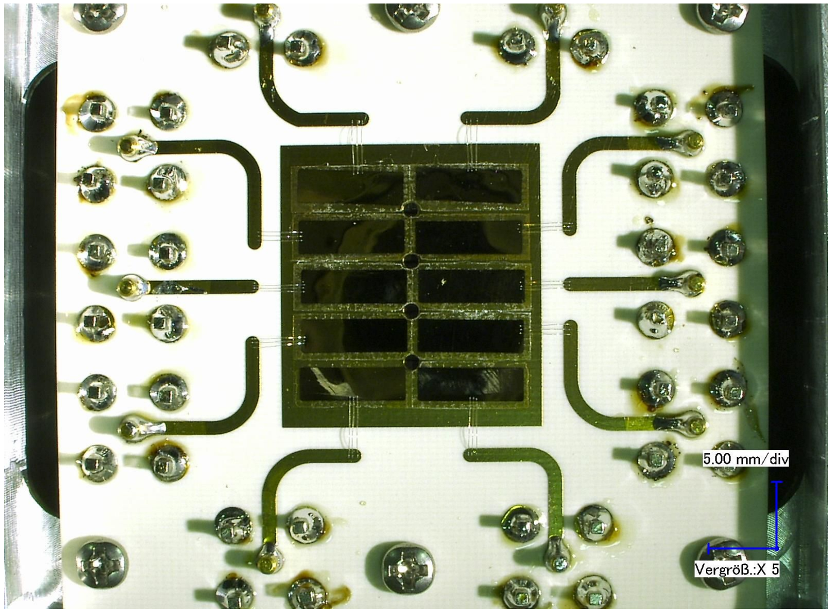


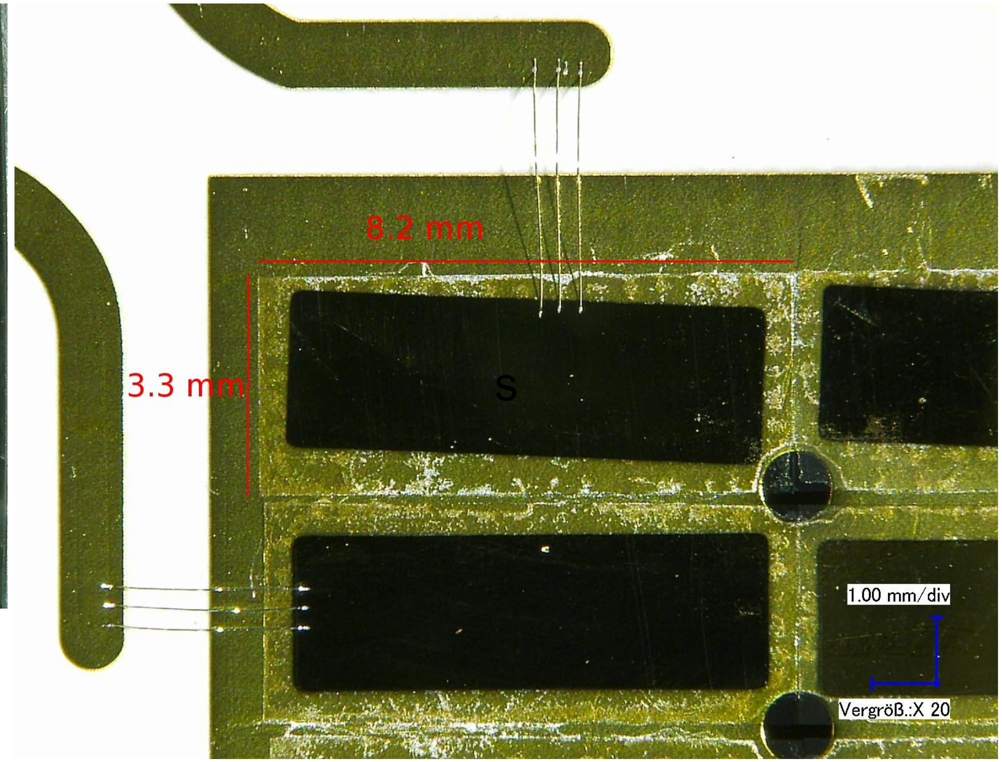
1. Time of signal depends strongly on location of carrier generation

2. Without trapping carriers create a 2nd signal.

→ Not applicable for our experiments.

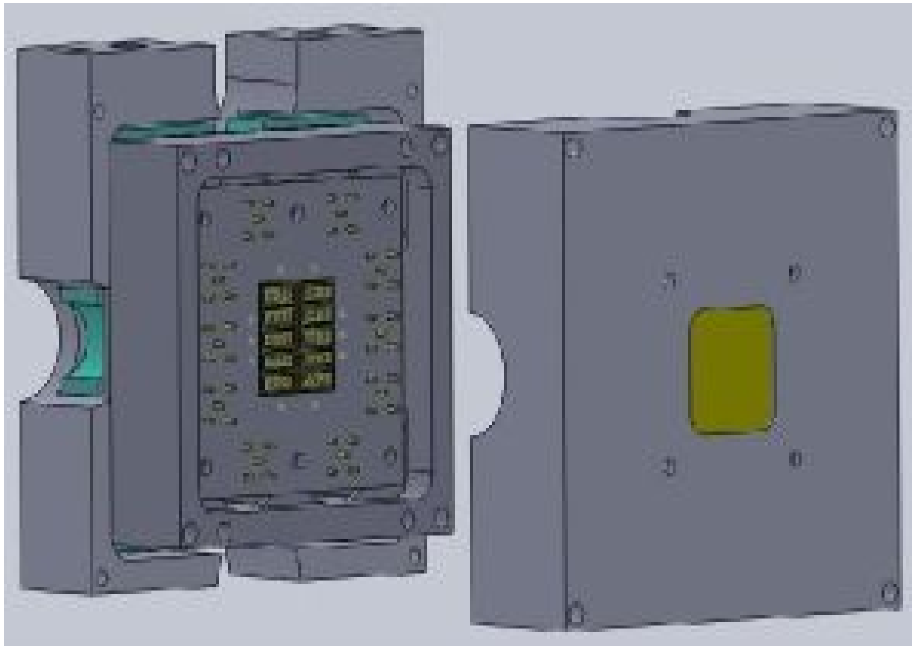
Thin large area detector





Detection Surface:	2.38cm^2
Thickness:	13 μm
Time constant:	3.3 ns
Ti-Pt-Au metallization	

Measures against saturation



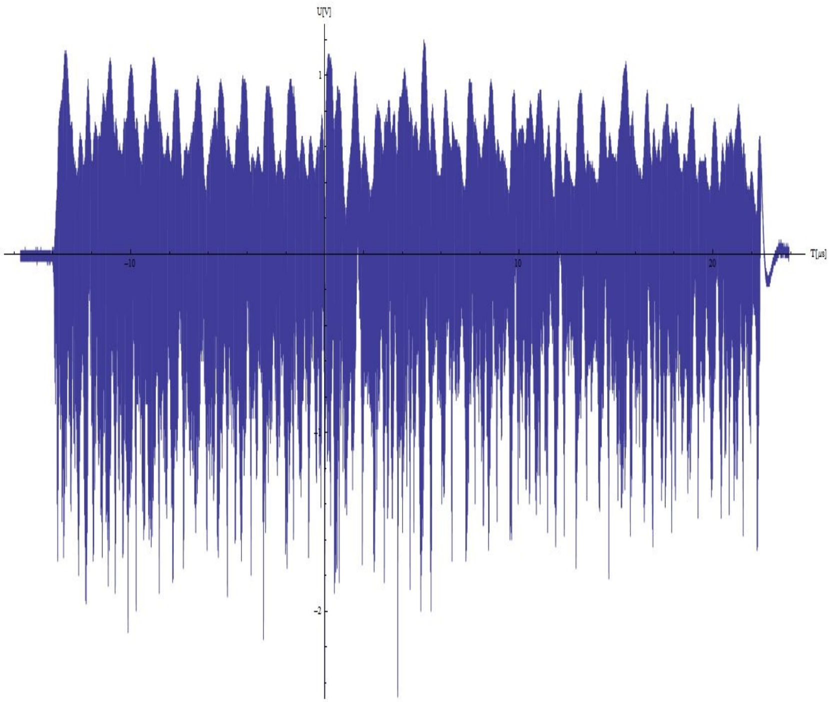
Protection from direct X-rays:

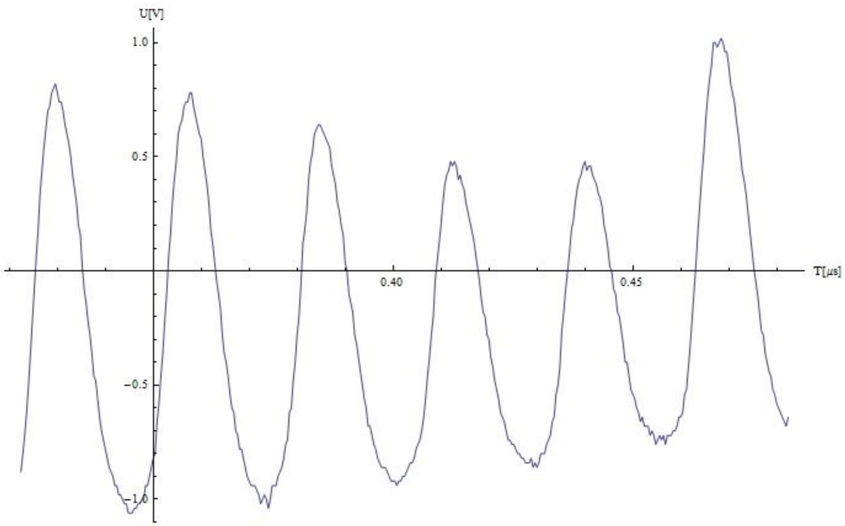
▪ Thin goldfoil (1.2 μm)

Protection from EMP:

▪ Entire detector in Faraday cage.
▪ Shielded cables with no sight to plasma or ion beam.

Results

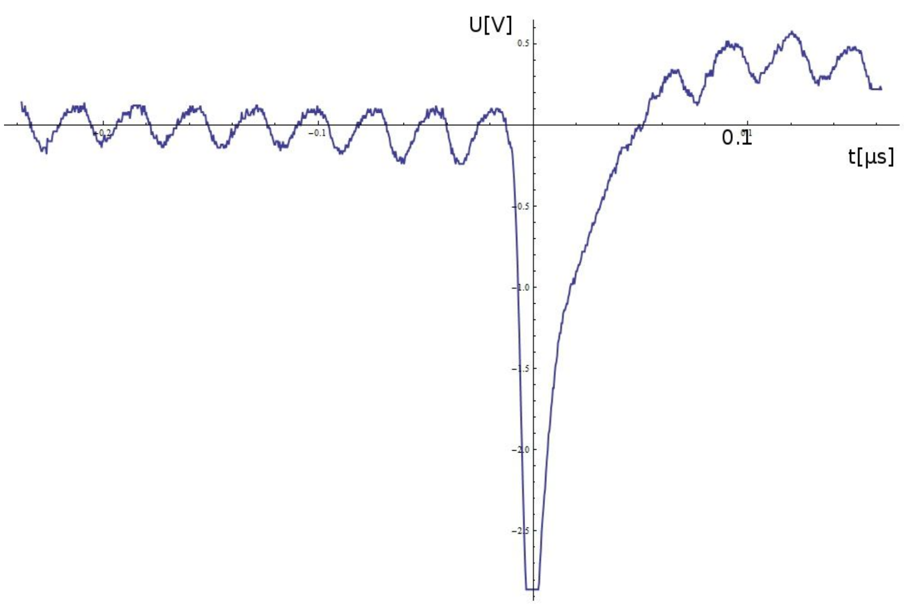




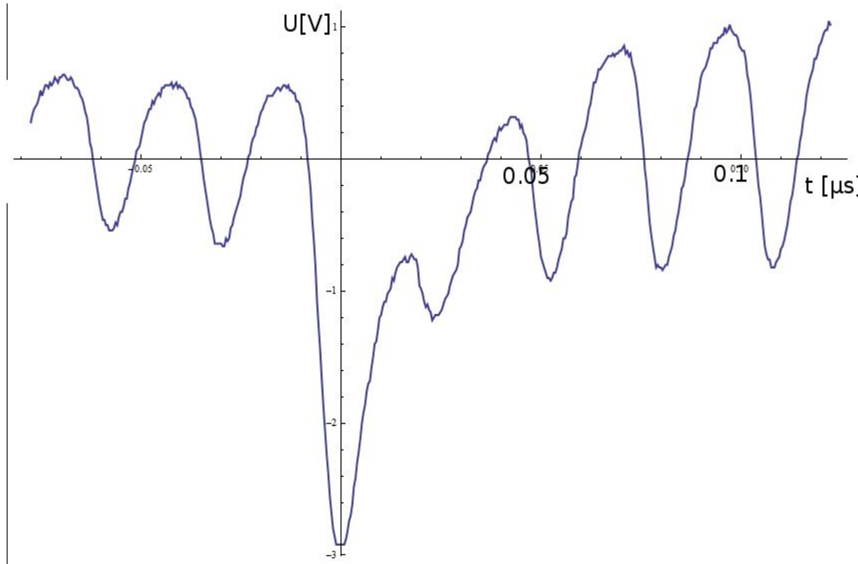
Δt =12-15ns

Few polarization influence seen.

Results



T= 60 ns



T= 20 ns

Saturation time below TOF of Ions: 50ns.

Detector showed its functionality and will be used in future experiments. Current data are beeing analyzed

Thank you for your attention and merry christmas.

Thanks to...

TECHNISCHE UNIVERSITÄT DARMSTADT

- Michael Träger
- Elèni Berdermann
- Bettina Lommel
- Witold Cayzac
- Bernd Zumbach
- Alexnader Frank
- Plasma physics Group

HELMHOLTZ GEMEINSCHAFT