Custom made components for Transient Current Technique

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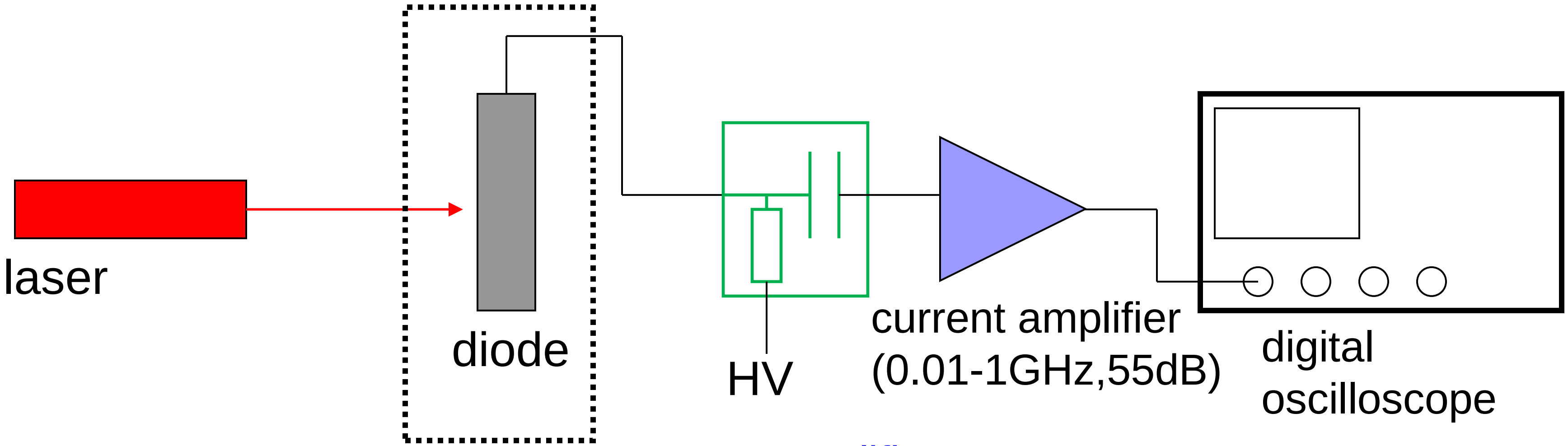
Motivation

- Equiping Faculty of Physics of Univeristy of Ljubljana with TCT setup for undergraduate student practicum exercise.

- A lot of experience in TCT → some limitations/problems/ inconveniences with commercial products …
  - Amplifiers:
    - frequent break down of commonly used MITEQ-AMP
    - need for very large gain – to get the amount of generated e-h pairs as small as possible to avoid plasma effects ($n_{e-h} \sim N_{eff}$)
      - Conventional TCT with focused short wavelength lasers
      - Edge-TCT, PS-TCT where beam is focused to few μm
    - to get reasonably priced device for multi-channel setups, where the price of around 1000$/piece can lead to substantial costs
  - Bias-T
    - Limited HV performance
    - Limited bandwidth
    - No integration Bias-T/amplifier (particularly useful if space is an issue)
  - Lasers
    - low cost/simple design

TCT experimental setup - general



Laser:
- custom made
- Commercial at CERN

Bias-T:
- custom made
- Picoseconds

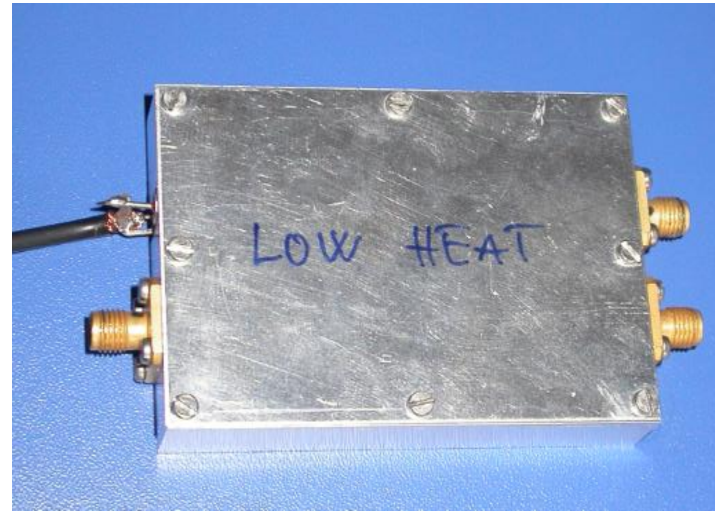
Amplifiers:
- Miteq (0.1-1600 MHz) - CERN
- Miteq (0.01-2000 MHz) – IJS
- Philips (0.01-1800 MHz) – CERN
- Custom made (<<0.3-2000 MHz) –IJS,CERN

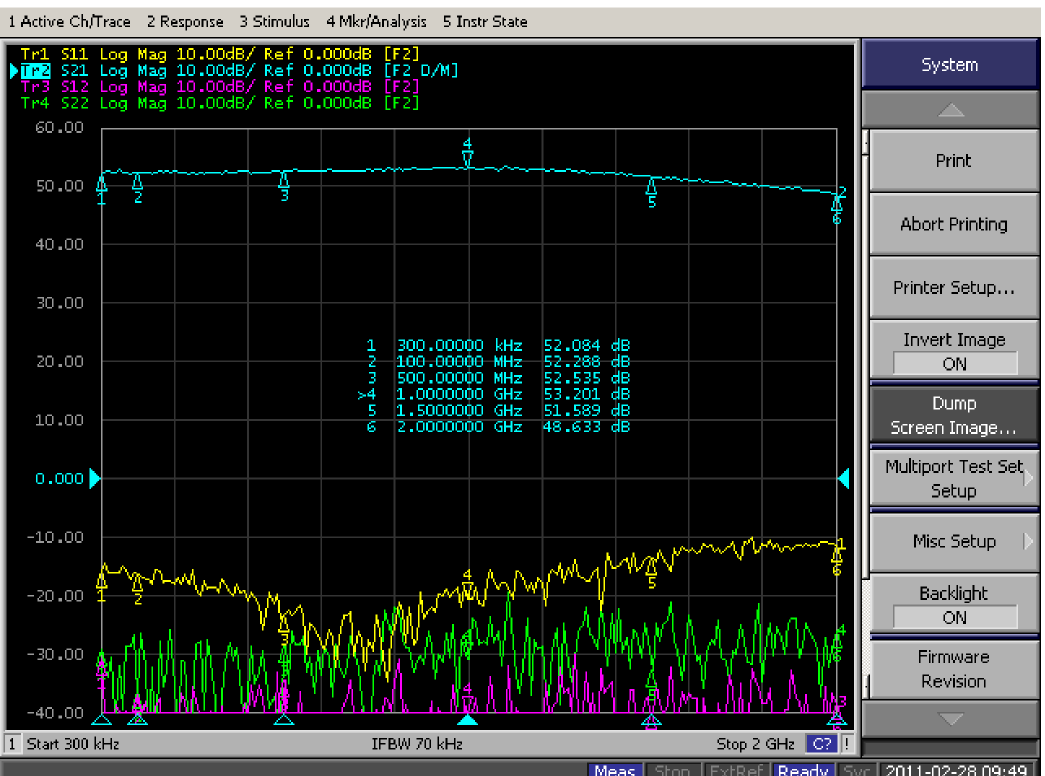
Devices used in tests:
- CERN ($\Phi_{eq}=3\cdot10^{13}$ cm^{-2} and $3\cdot10^{14}$ cm^{-2})
- IJS (high/low resistivity non-irradiated detector)

All were biased over Bias-T with the same length of cables

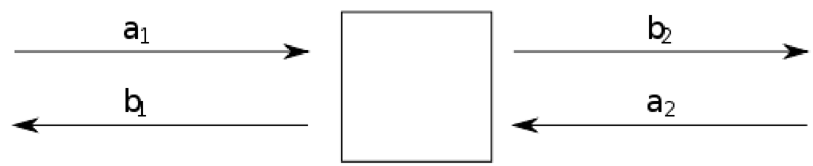
Custom made amplifier

- Optional dual gain (higher gain)
- Bandwidth <<0.3-2000 MHz, the network analyser could not go below 300 kHz
- Small power consumption (+12 V) – initial problem with heating solved – good for use in thermally enclosed setups





What do the numbers on the plot mean?

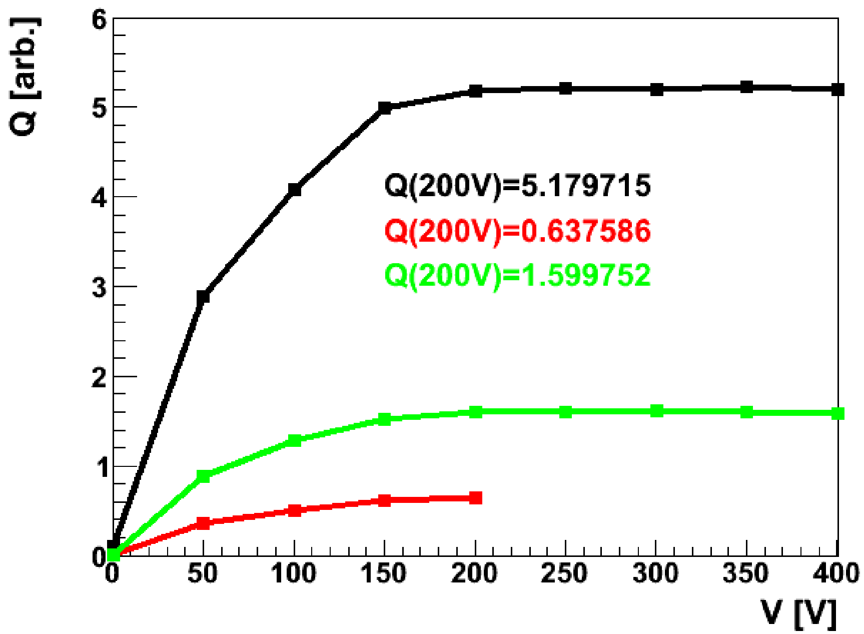


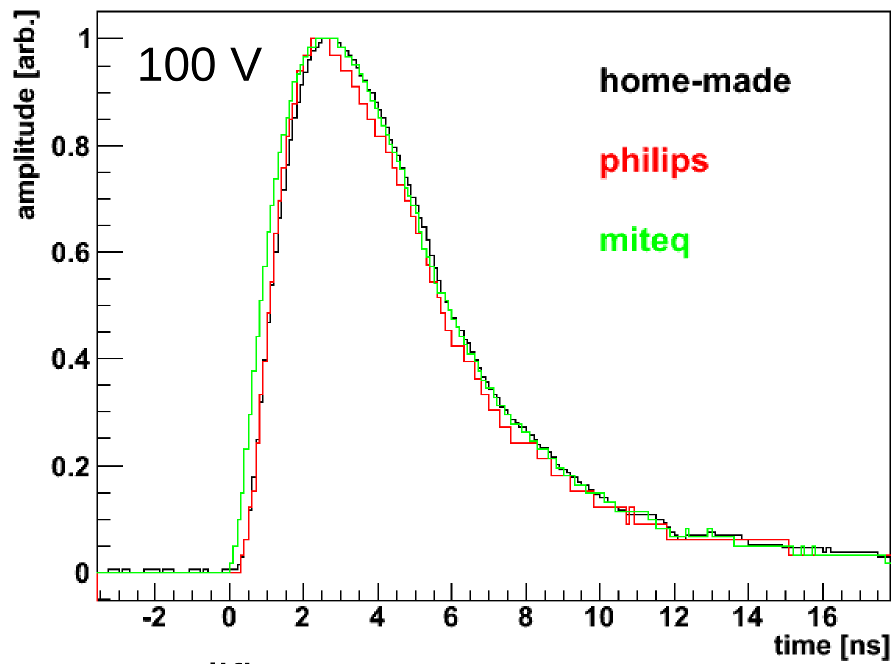
$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

Gain of the amplifier

Tests at CERN (CERN setup)

Identical setup for all three amplifiers used
(bias of the sensors is from front contact via Picosenconds Bias-T)



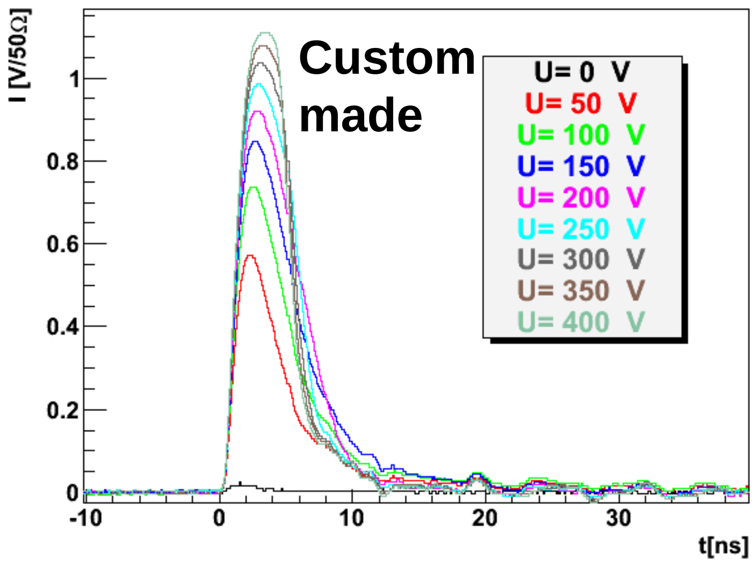


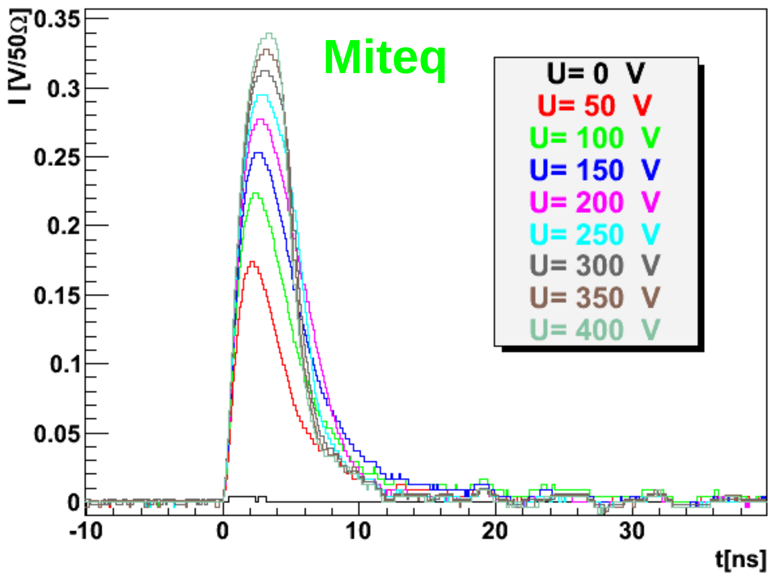
Detector (STM 331, 1 kΩ cm, n-type)
- irradiated with protons to $3 \cdot 10^{13}$ cm^{-2}, no SCSI
- V_{fd}~300 V before irradiation
- electron injection

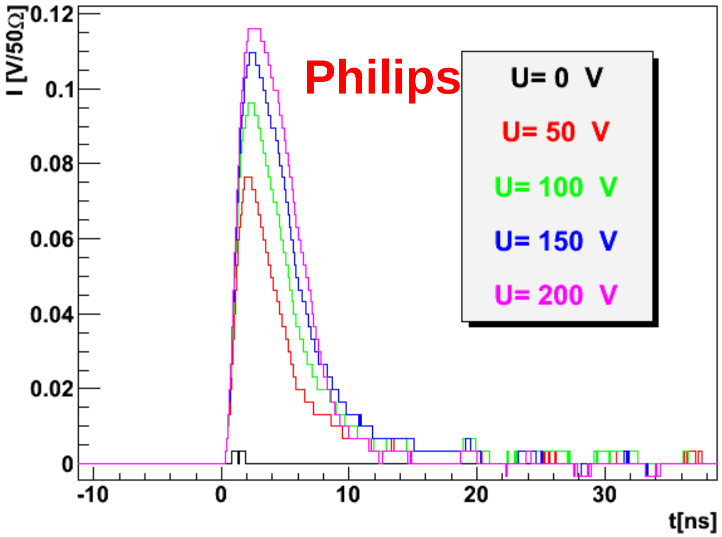
Amplifiers
- **Custom made (<300 kHz-2 GHz)**
- **Philips (0.01-1800 MHz)**
- **Miteq (0.1-1600 MHz)**

Similar rise time – not amplifier dependent
Large difference in gain – custom made is few m.i.p. sensitive

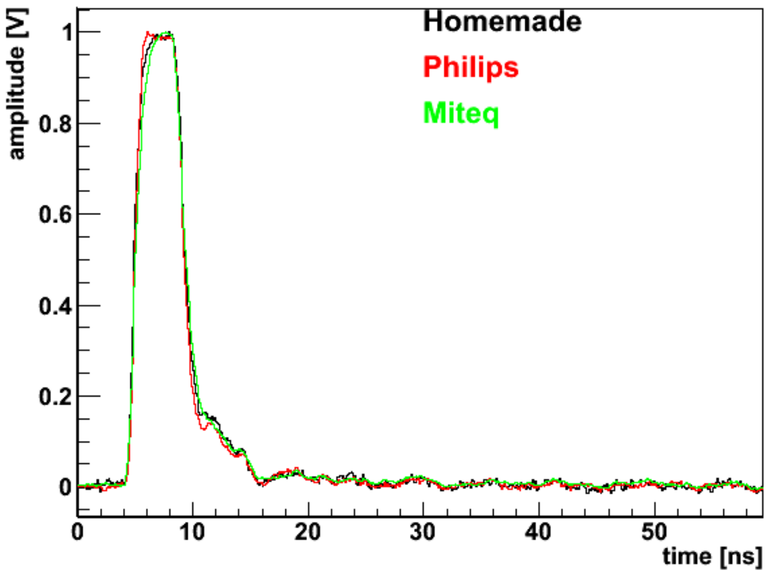
Voltage scans (CERN)

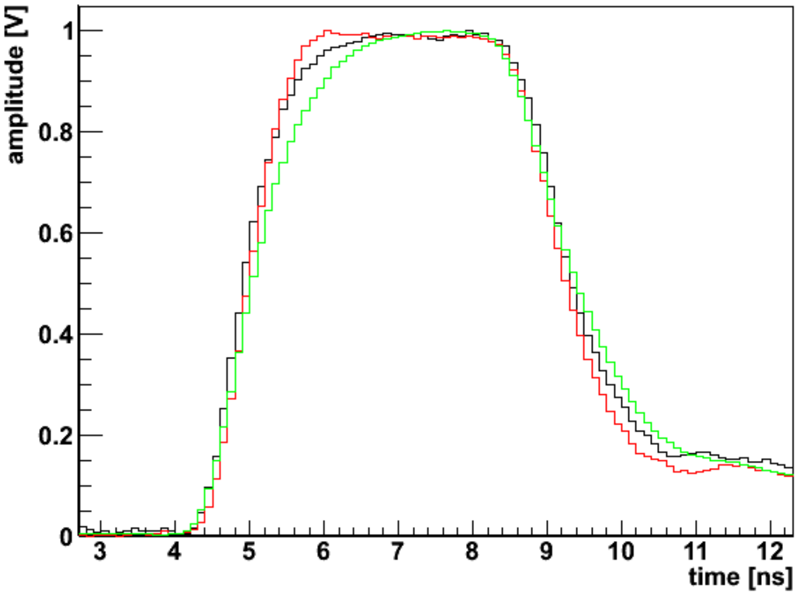






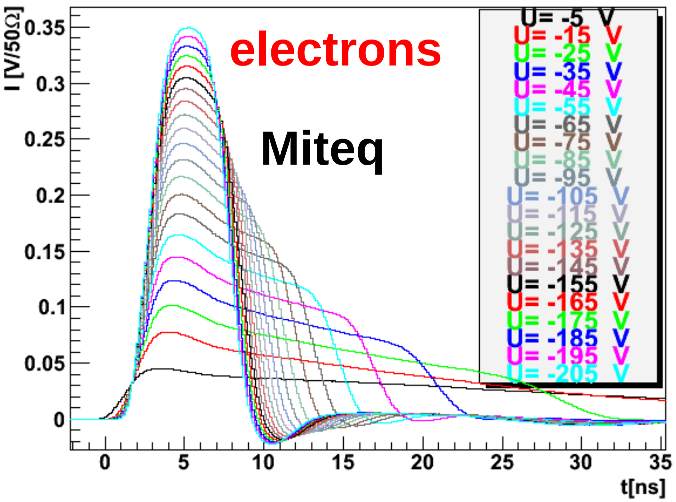
Rise time (CERN)

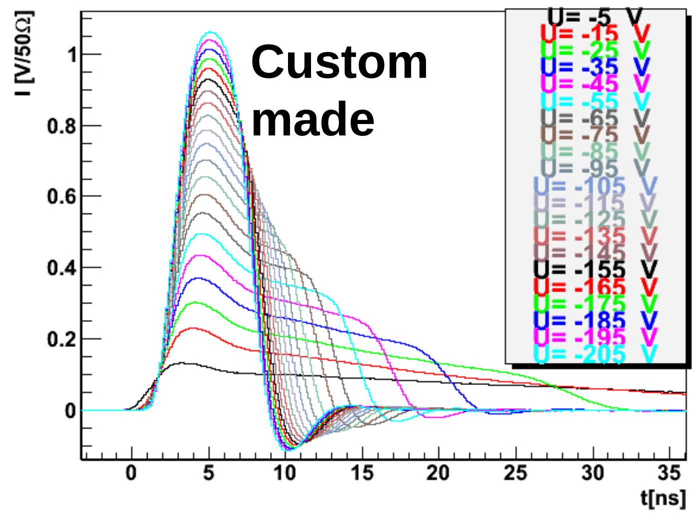


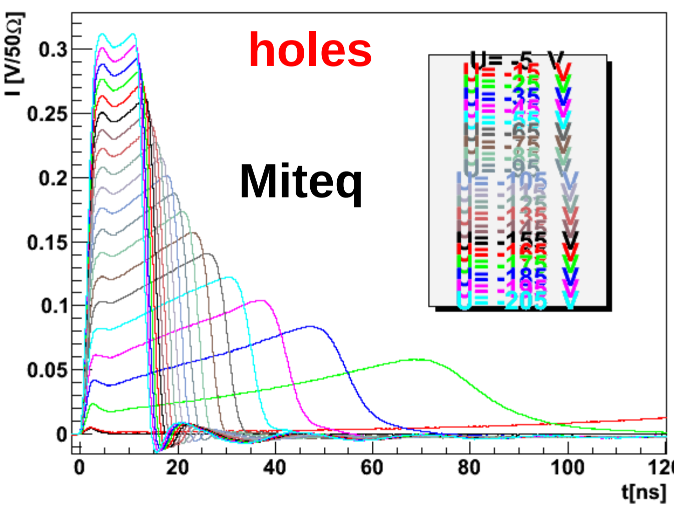


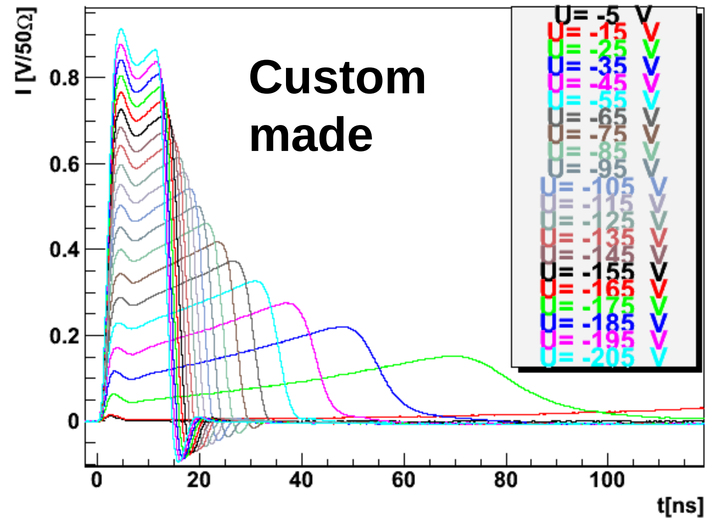
- n-type after 3e14 cm^{-2}, V_{fd}~200 V, 400 V, electron injection
- Plots normalized to 1 (maximum point)
- approximately the same response from all three of them, but Miteq seems to be somewhat slower than the two others (expected)

Non-irradiated sensor (JSI setup)



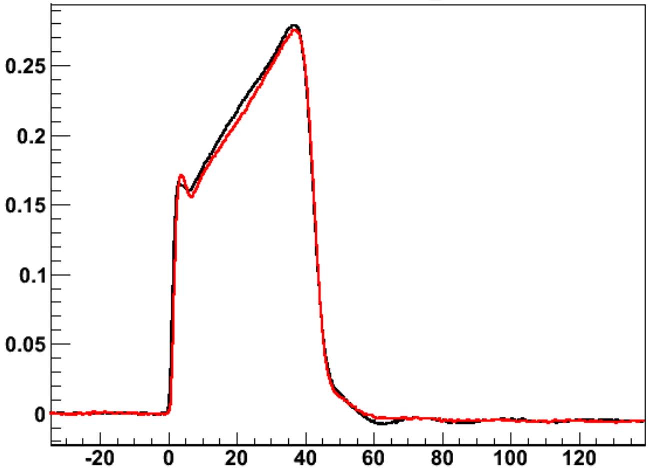


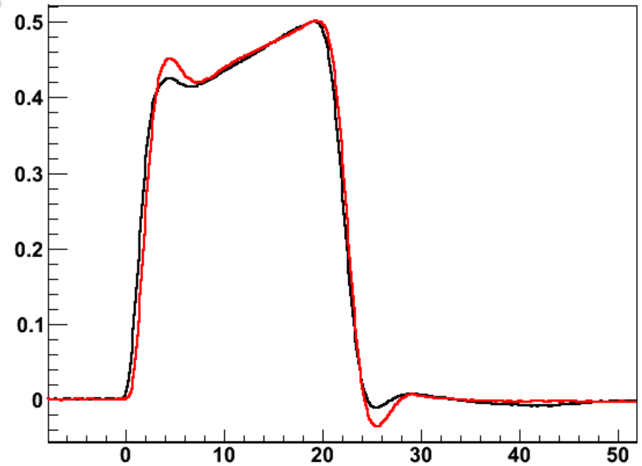


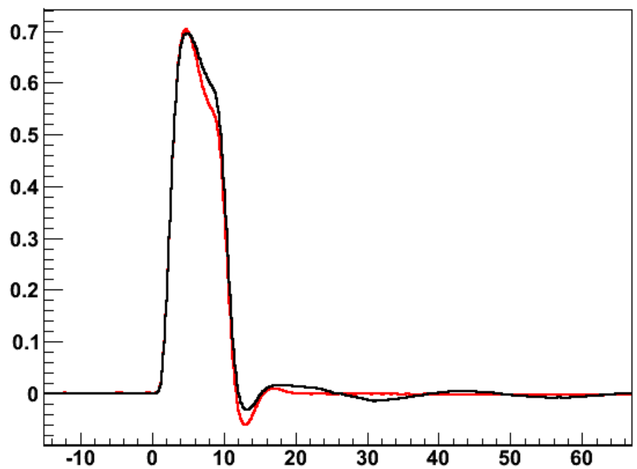


- Electron injection – almost equal response apart from the difference in amplification (factor of 3)
- Not optimized setup for ns scale measurements (reflections)
- Laser was a “slow” one (~1.4 ns FWHM)

Detailed comparison (JSI setup)







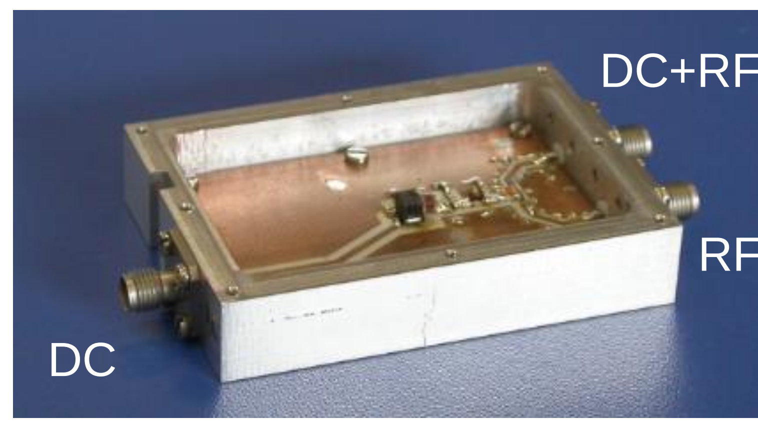
RED: Custom made

BLACK: MITEQ

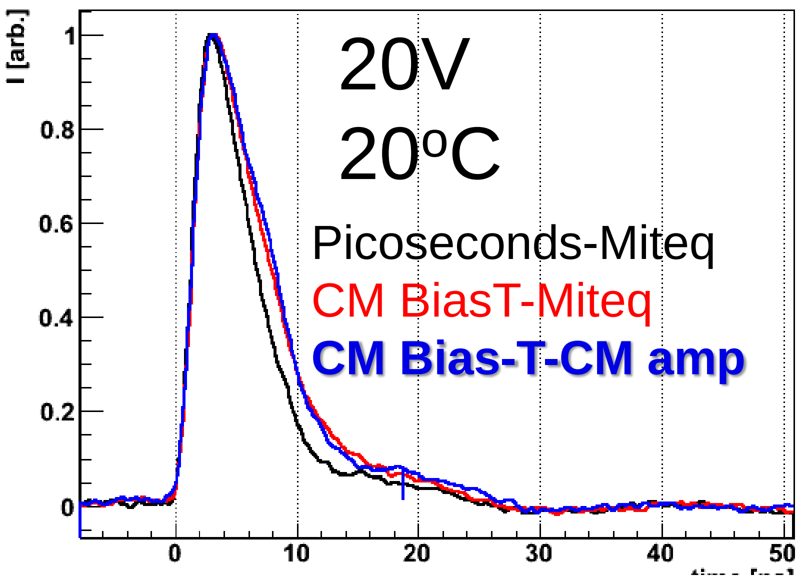
- less ripple after the signal has gone for custum made amplifier
- Bandwidth is not entirely the same

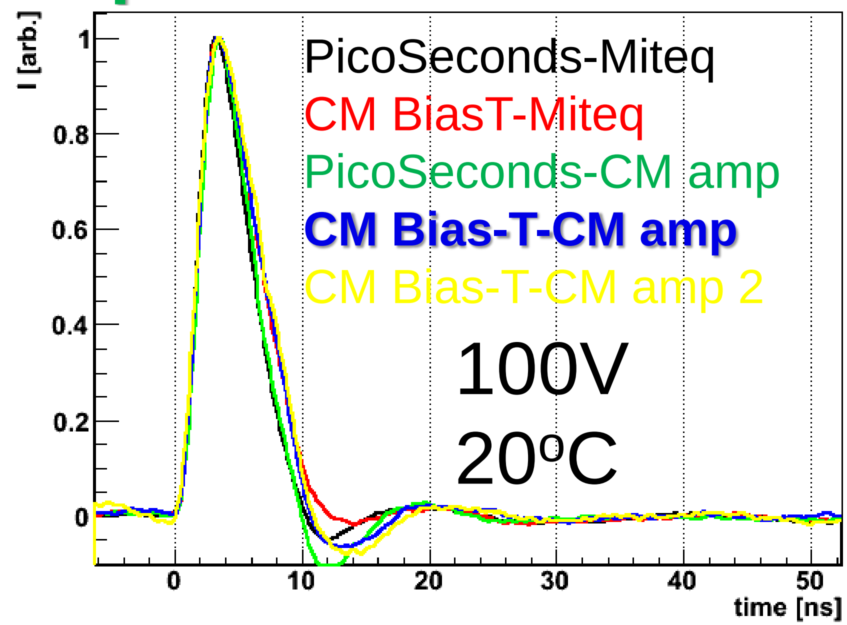
Bias-T

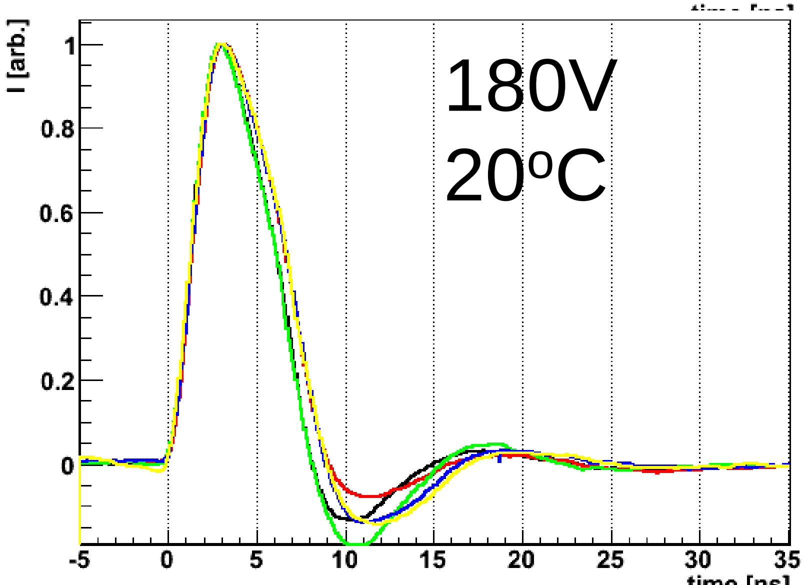
- very few Bias-T for GHz range with HV capabilities. Most commonly used Picoseconds which has some limitations
  - limited to 1kV
  - Bandwidth limit at lower side is relatively high - 750 kHz
- custom made design can sustain high voltages up to 2.5 kV (currently tested to 1100V)
- will/can be integrated in the same box as amplifier – compact design



Comparison of the pulses with different combinations of Bias-T - amplifiers





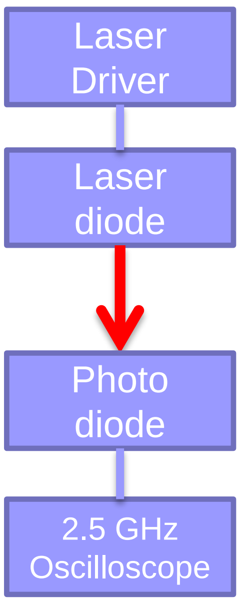


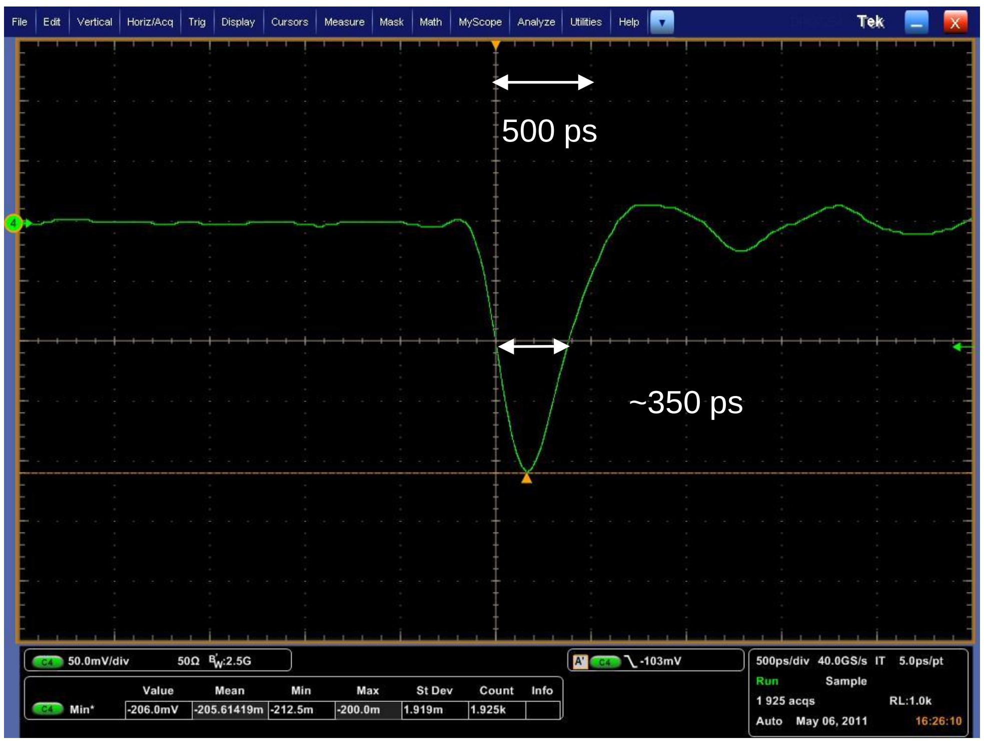
W336 diode, FZ n-type, 2 kΩcm, V_{fd}=180, electron injection – front ill., laser 1.4 ns FWHM

- **No significant difference between any of the configuration**
- **Broader band-width of the custom made Bias-T (low V_{bias})**

Laser

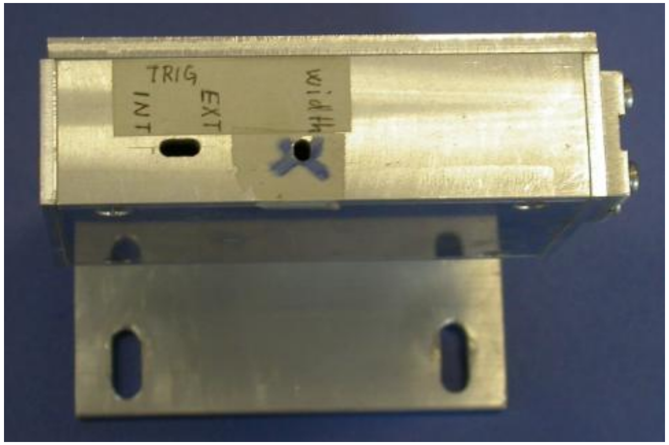
- The driver is general for red/IR (tested), but any suitable diode can be used
  - Max current pulse 350 mA (the current is tuned to laser)
  - Repetition rate from 0 to 150 MHz – depends on the laser diode
- Laser power should be regulated by using neutral density filter (absorber)
- The laser can be triggered externally (pulse generator) or internally (several predefined frequencies, trigger at the output)
- Power (~-5V)





Parameters of the laser as measured with photodiode (**real parameters are probably better**)

- FWHM <= 350 ps
- Rise time (10-90%) ~150 ps

The red laser used in tests shown is a “slow” version with FWHM of around 1ns.

If you are interested ...

- in anything (any piece) shown please contact me or Marko.Zavrtanik@ijs.si
- in complete TCT-setup … we will produce some
  - comes together with DAQ/Analysis software ☺
  - diode holder, bias voltage-filter …

Pieces will be much cheaper than commercial products, but I can not tell prices now …