Diagnostic Test-Beam-Line For The MESA Injector

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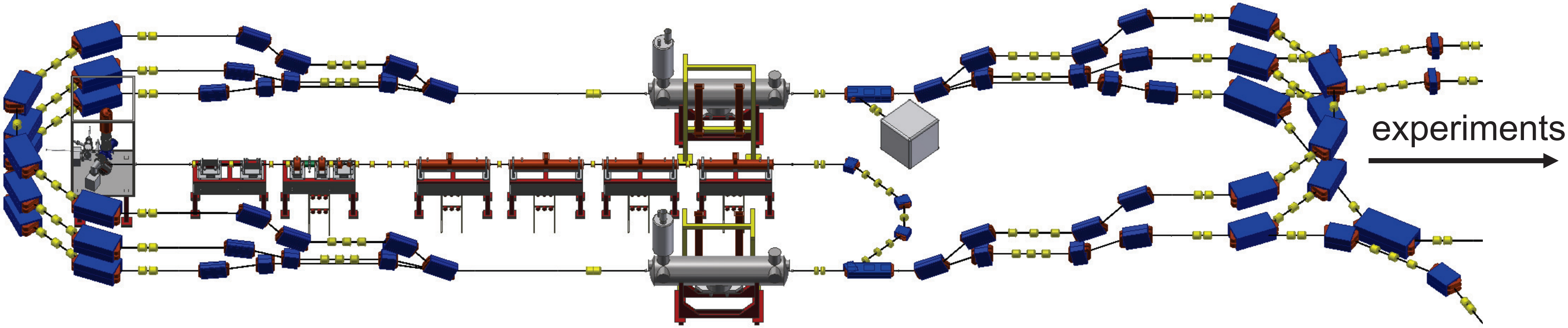
Content

Introduction - Motivation

- beam diagnostics for MESA
- 100 kV dc-electron gun
- normal conducting injector up to 5 MeV
- 1.3 GHz cw electron beam
- 155 MeV, 150µA polarized beam - EB-Mode
- 105 MeV, 1 mA (10 mA @ stage 2) - ERL-Mode
- bunch charge up to 8 pC (10 mA @ 1.3 GHz)



Introduction - Motivation

Important properties of the source/injector

- emittance must be much smaller than the acceptance of the accelerator → $\varepsilon_n \leq 1 \mu m$
- high extractable current
- long life time → stable photo emission
- reliable
- polarized an unpolarized beam

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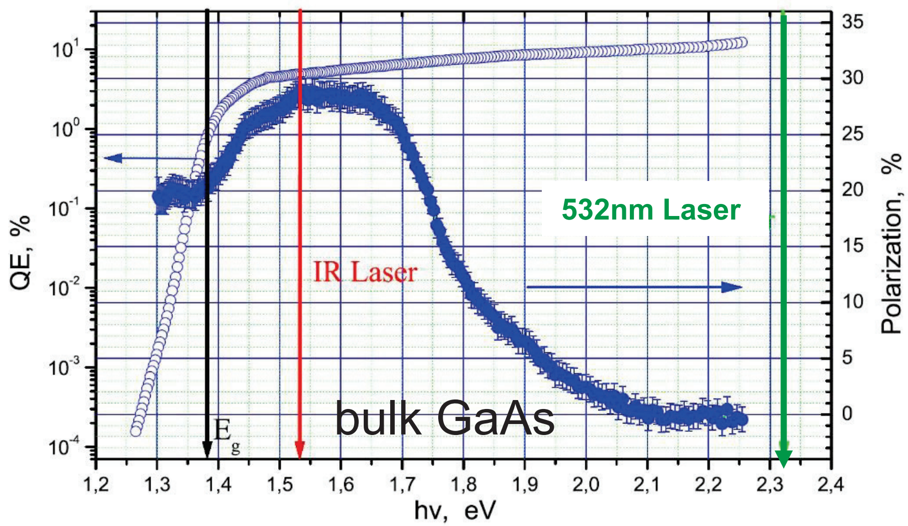
Introduction – Photo cathodes

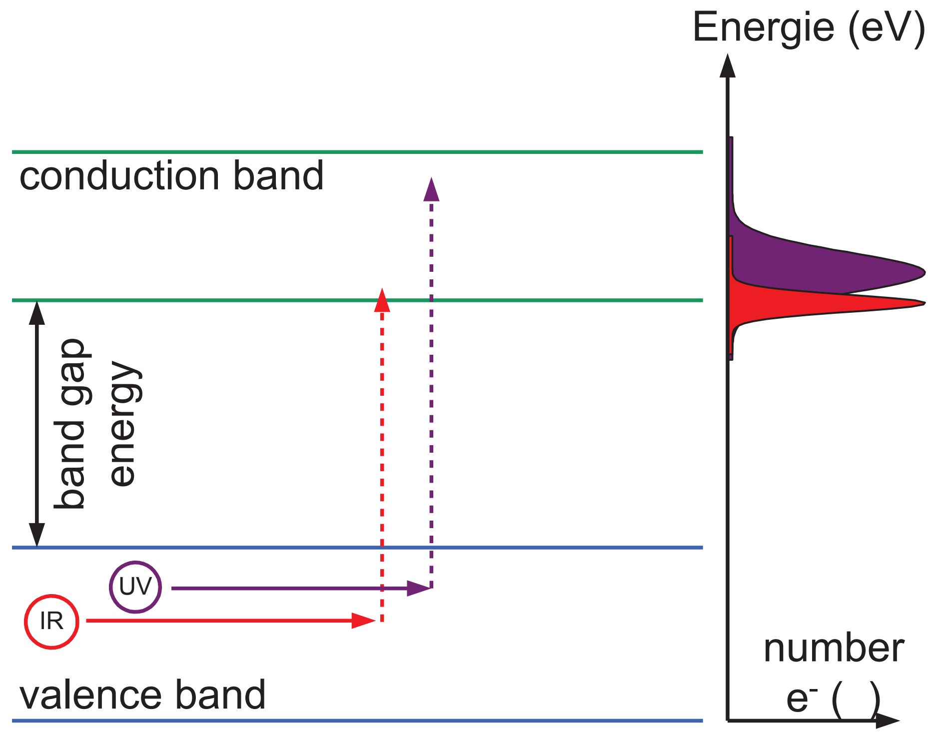
PRiSMA

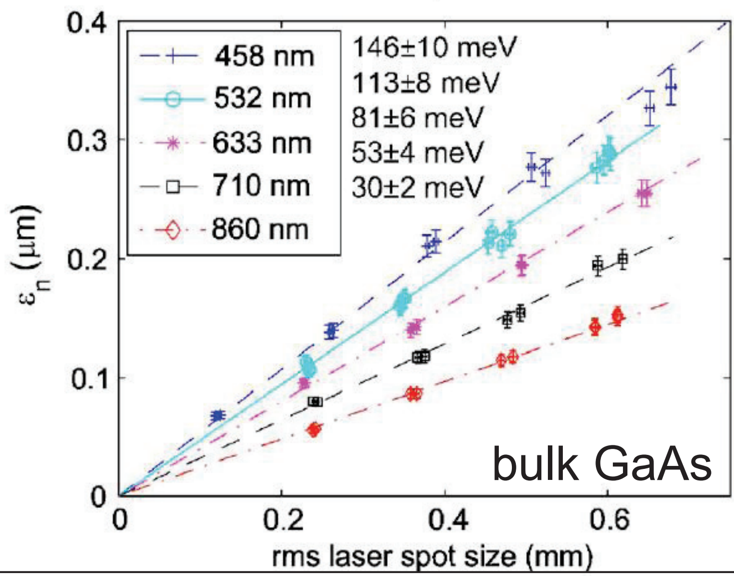
MAINZER MIKROTRON



Measurement St. Petersburg – **Y. Yashin**

photon absorption in semiconductors





Thermal emittance and response time measurements of negative electron affinity photocathodes
JOURNAL OF APPLIED PHYSICS 103, 054901 2008 – **I.V. Bazarov**

Introduction – Photo cathodes

- charge life time of photo cathode $Q \cong 700\ C$ (our result)
- aver. electron current for experiment $I = 1\ (10)\ mA \rightarrow \dot{Q} = 3.6\ (36)\ {}^{C}\!/_{h}$
- phase acceptance of the accelerator $\varphi_{acc.accept.} = 72°$

→ with dc electron source 80% of the charge is wasted

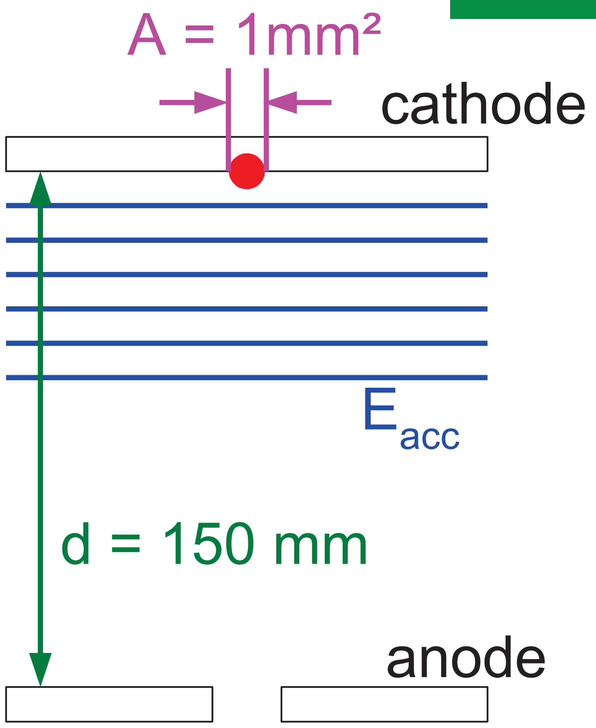
→ experimental time $t_{\exp} \leq 40\ (4)\ h$

- with dc electron source 80% of the charge is wasted → **pulsed source increase the operational time by a factor 5**

MESA would need pulses with a length of 160 ps and a repitition rate of 1.3 GHz

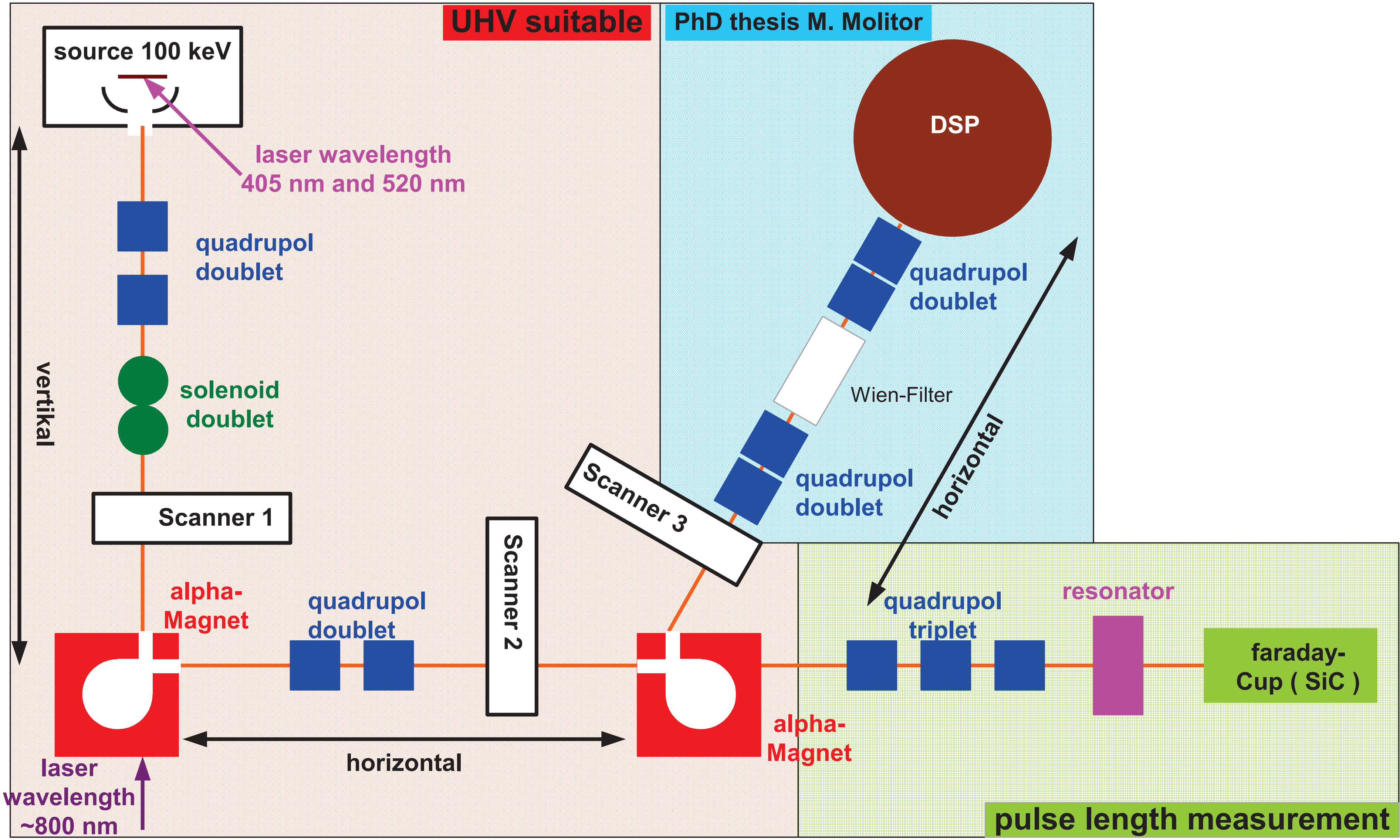
Introduction – Space charge

- current limit $$I_{sc,\lim} = p_0 \frac{A}{d^2} U^{3/2}$$
- acceleration voltage $$U = 100\ kV$$
- perveance $$p_0 = 2{,}33 \cdot 10^{-6} \frac{A}{V^{3/2}}$$
- current limit with source parameters $$I_{sc,\lim} \cong 3\ mA$$

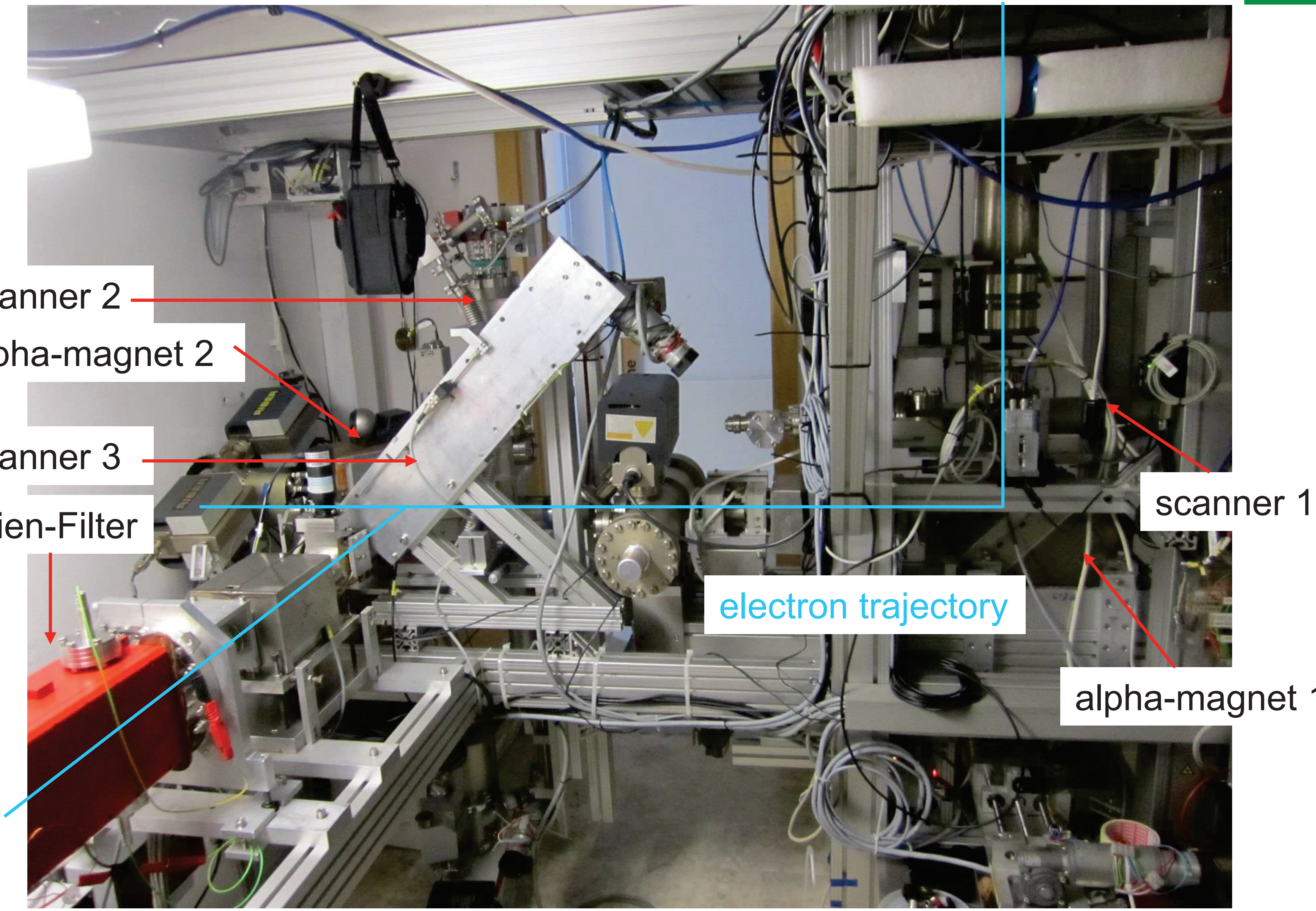


- current limit of the source fulfills MESA stage1
- new 200 kV source in production

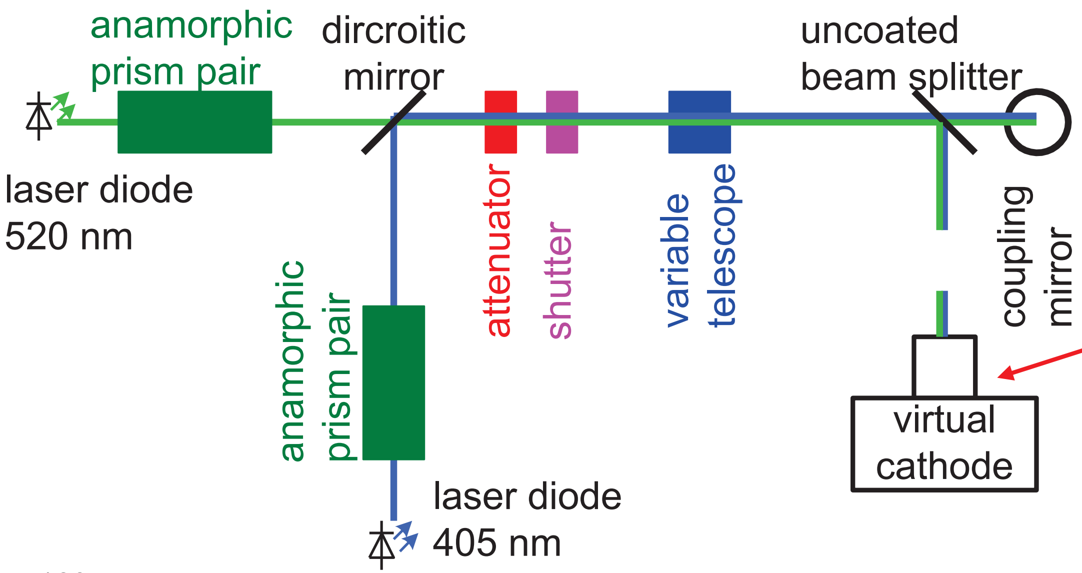
Components Overview of PKA2

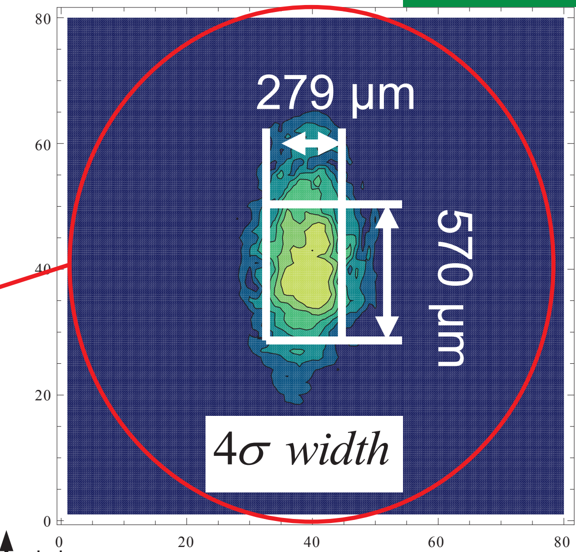


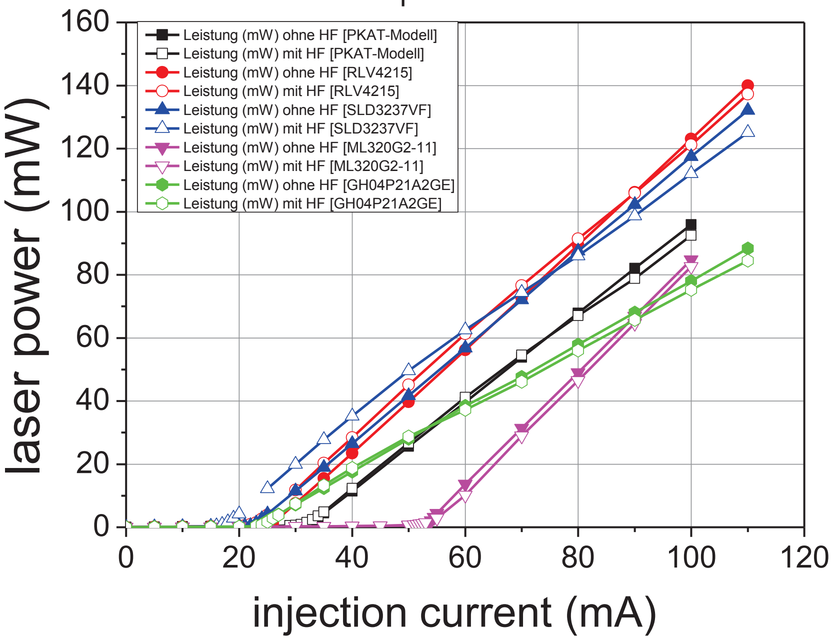
Components
Overview of PKA2



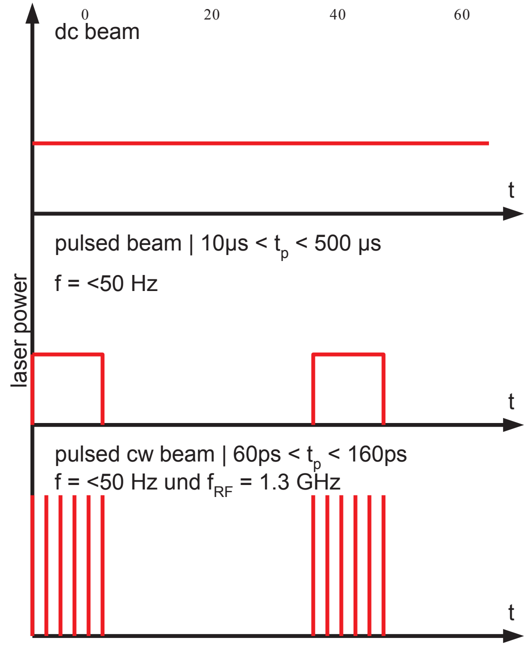
Components
UV-VIS laser system



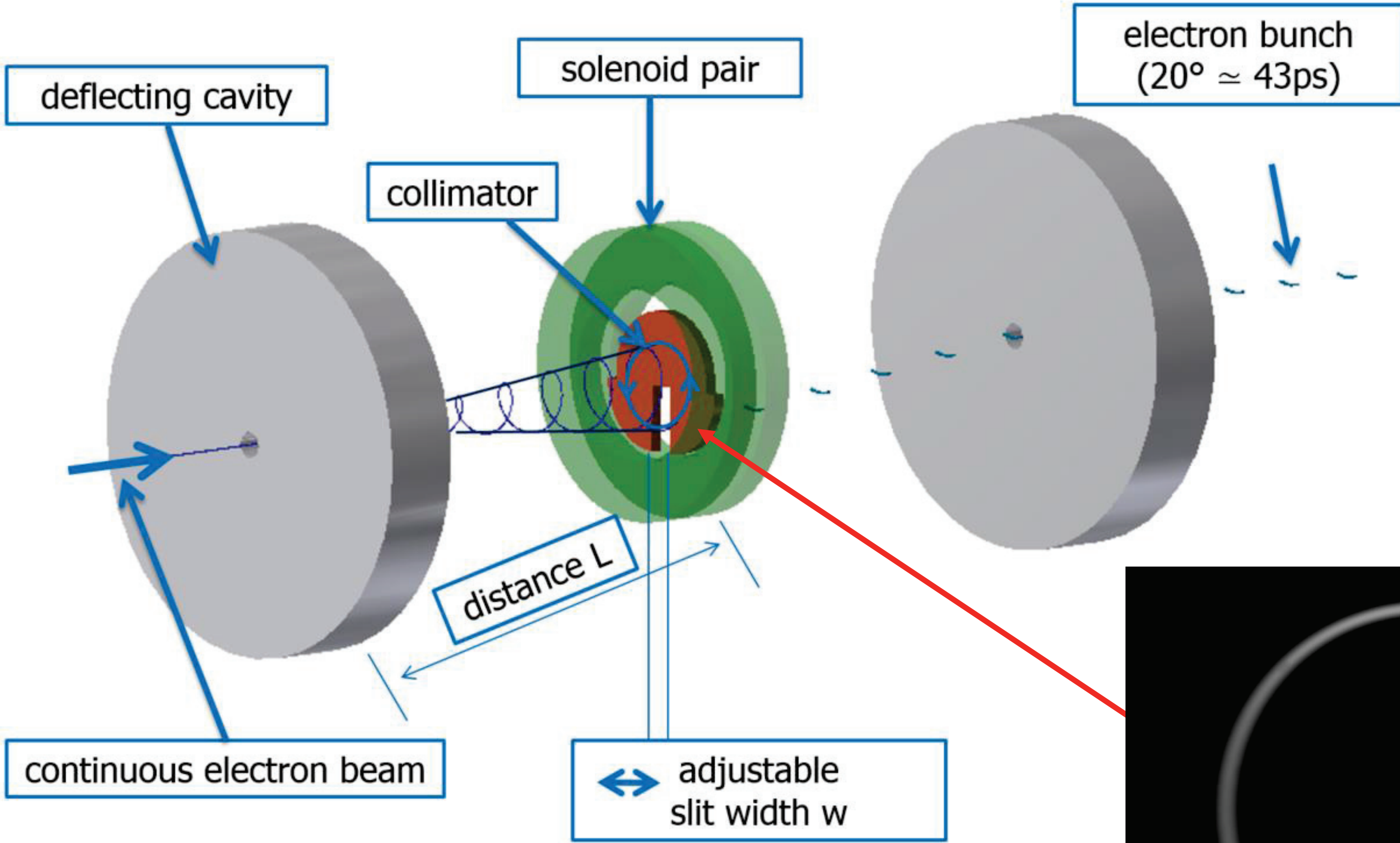




wave length	: 405nm & 520nm
dc-beam:	P_{max} < 300 mW
	$P_{avr.}$ < 300 mW
pulsed-beam:	P_{max} < 300 mW
	$P_{avr.}$ < 3 mW
pulsed cw-beam:	P_{max} < 3000 mW
	$P_{avr.}$ < 3 mW

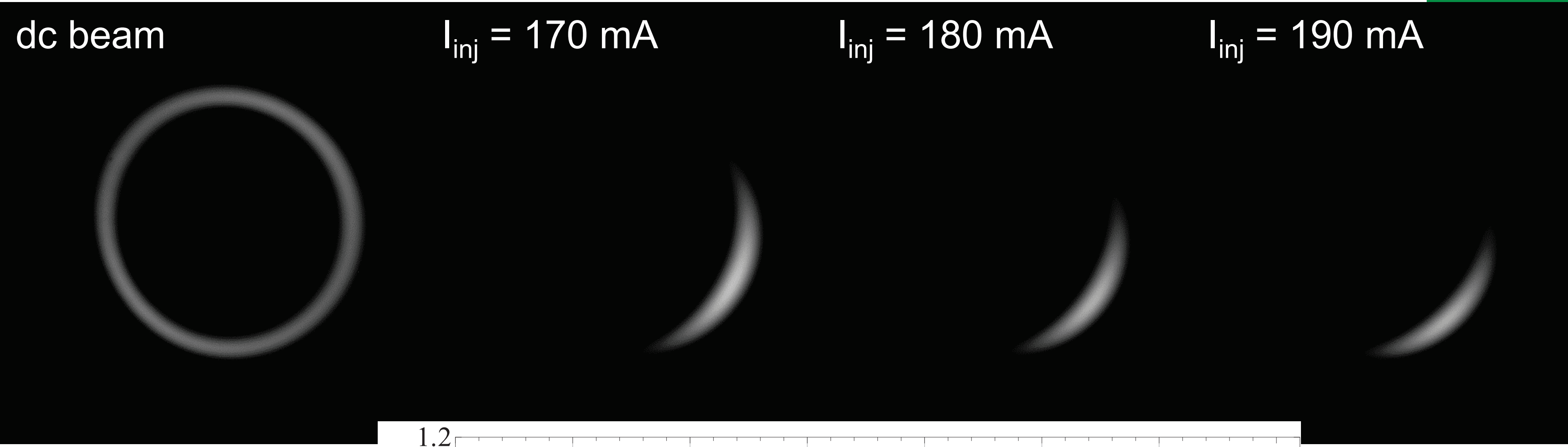


Components – Deflecting cavity



Diploma thesis: V. Bechthold

Components – Deflecting cavity



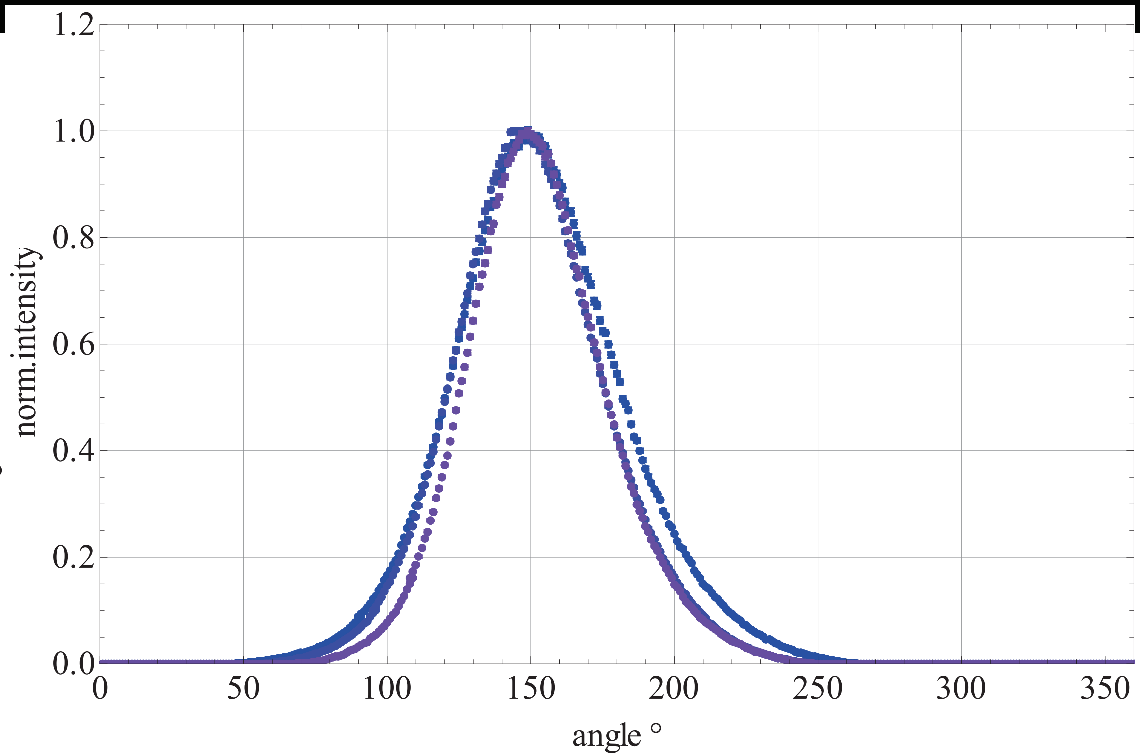
green laser diode

$\lambda = 520$ nm

$P = 120$ mW

$I_{th} = 120$ mA

transmission @ 120° > 95%



Components - Scanner

- Scanner 1
  - Ce:YAG Ø = 25 mm
  - wire (W Ø = 40μm)
  - 21 hori. & 21 verti. slits (w = 25 μm / 250 μm)
- Scanner 2
  - Ce:YAG Ø = 25 mm
  - wire (W Ø = 40μm)
  - 21 x 21 holes (Ø = 25 μm / 250 μm)
- Scanner 3
  - Ce:YAG Ø = 25 mm
  - Ce:YAG Ø = 25 mm with hole Ø 2 mm
  - Ce:YAG Ø = 25 mm with hole Ø 3 mm

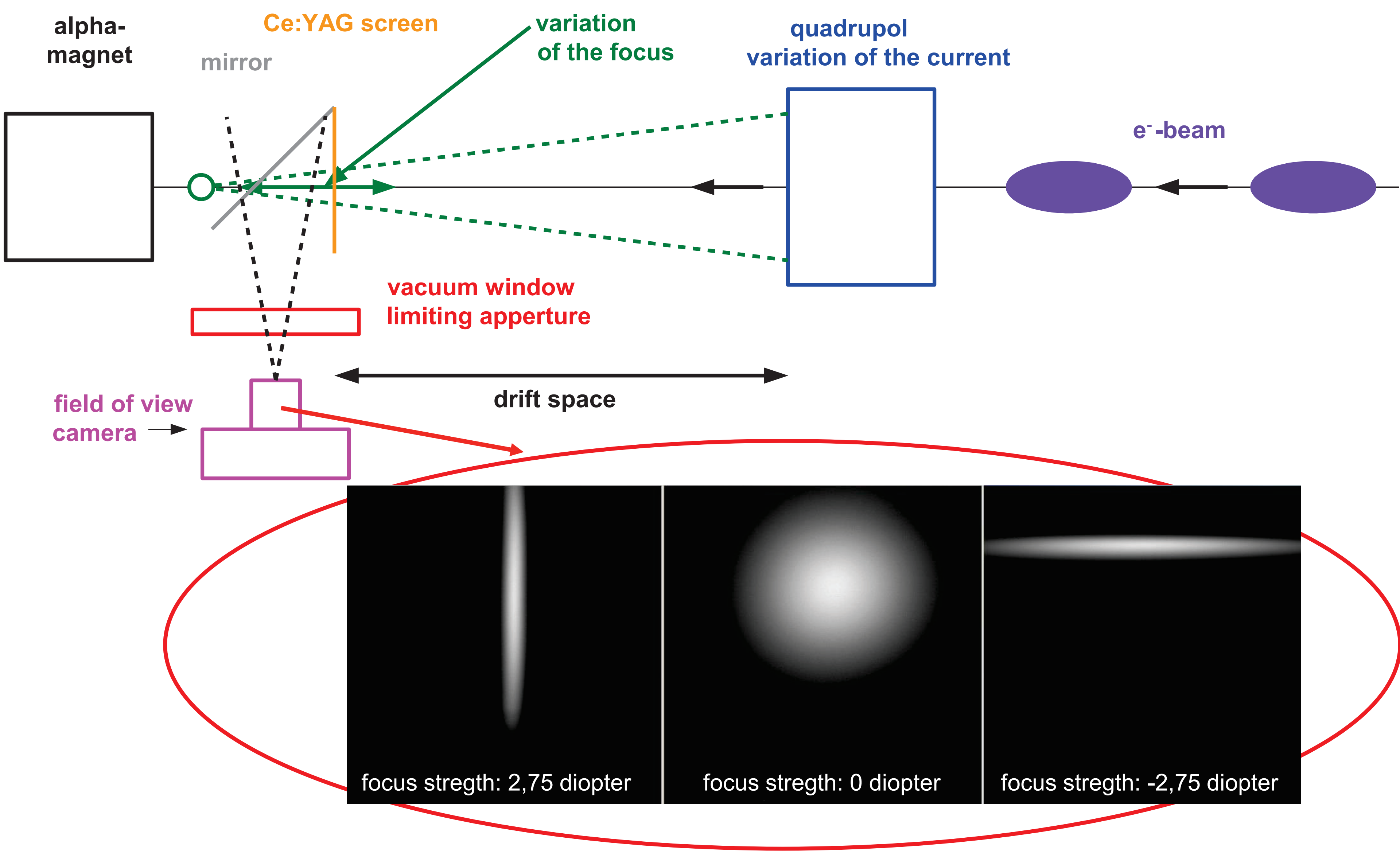
quadrupole scan
quadrupole scan
emittance measurement

quadrupole scan
quadrupole scan
emittance measurement

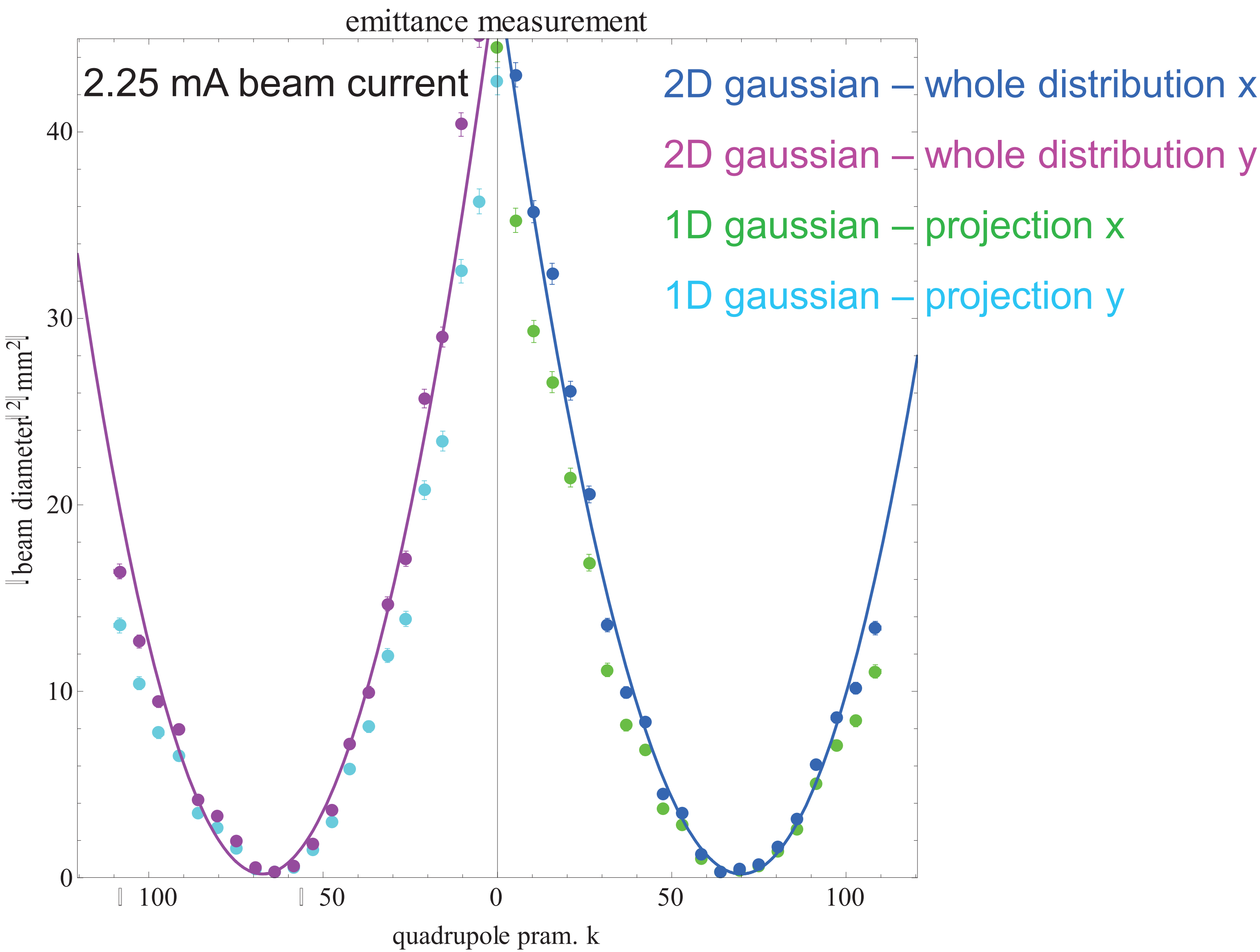
screen
(heli.correlated) halo
(heli.correlated) halo

Ce:YAG – Yttrium-Aluminium-Granat

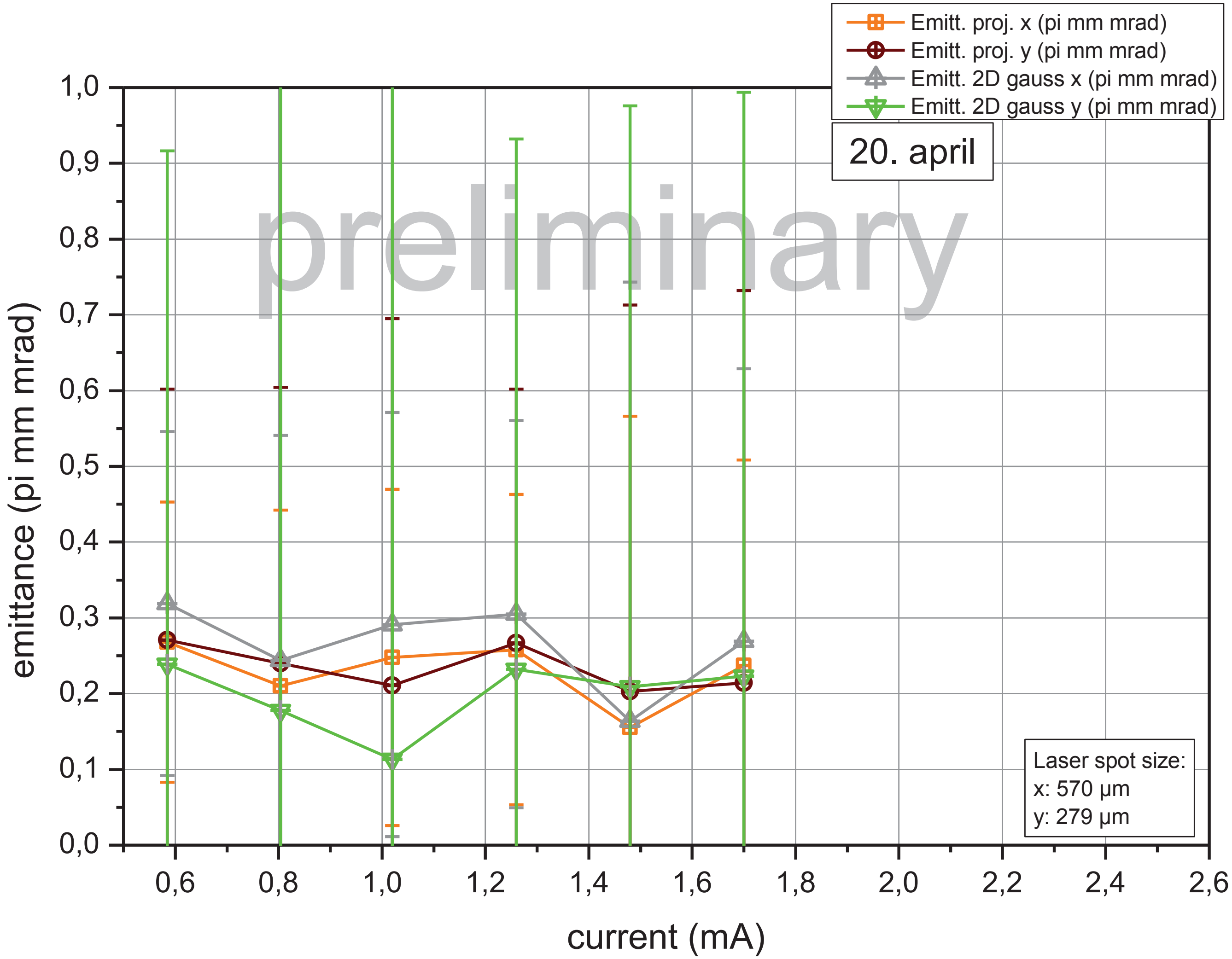
Results – Quadrupol-Scan



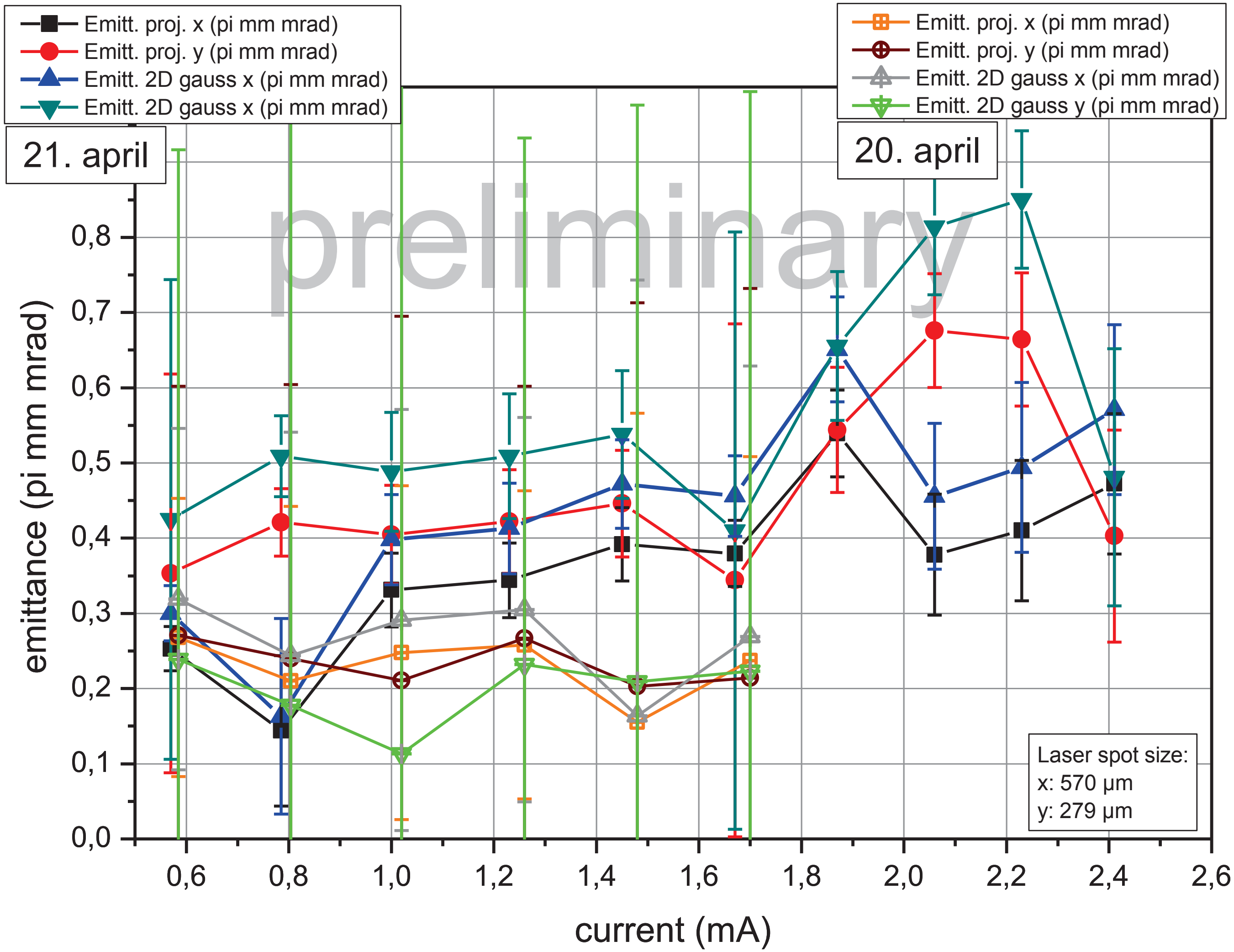
Results – Quadrupol-Scan



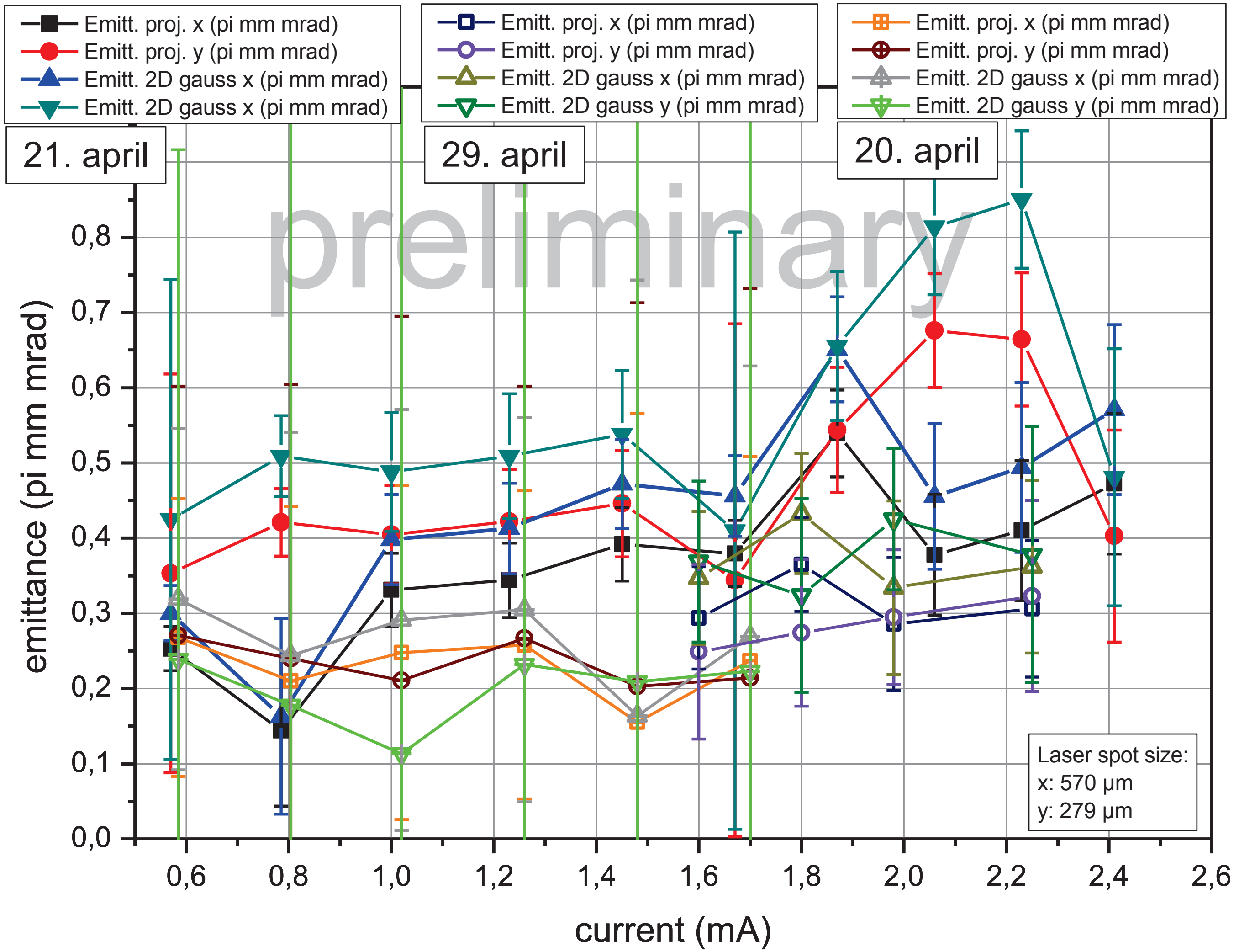
Results – Quadrupol-Scan



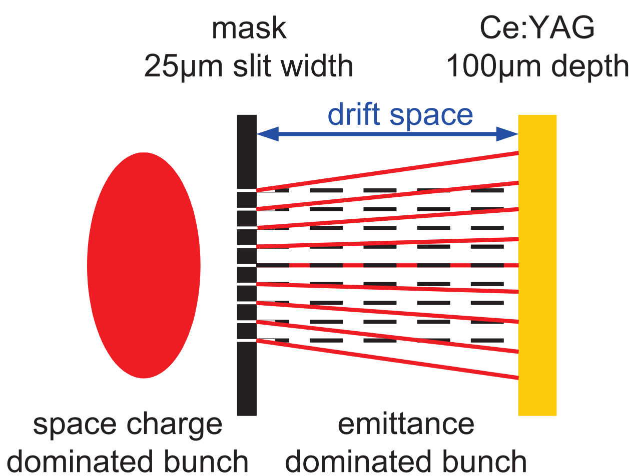
Results – Quadrupol-Scan

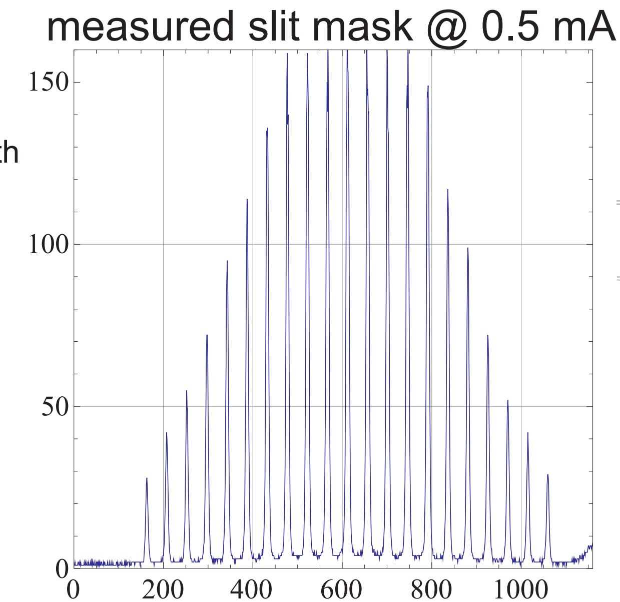


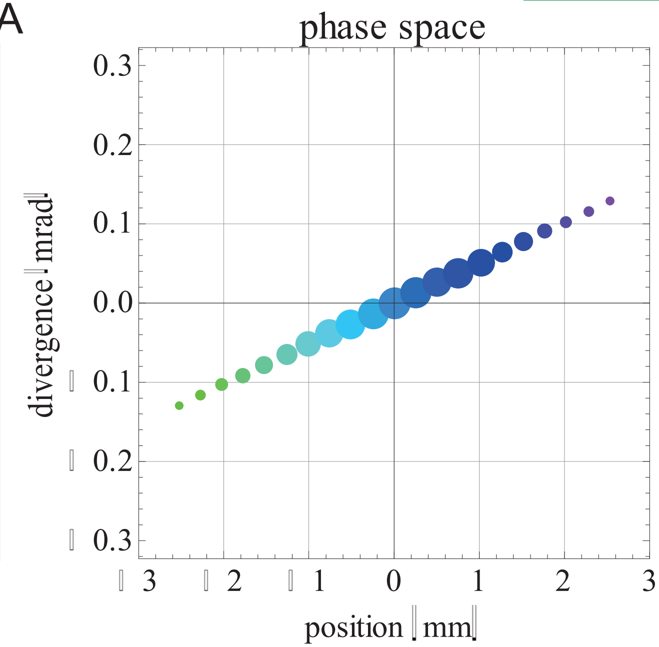
Results – Quadrupol-Scan

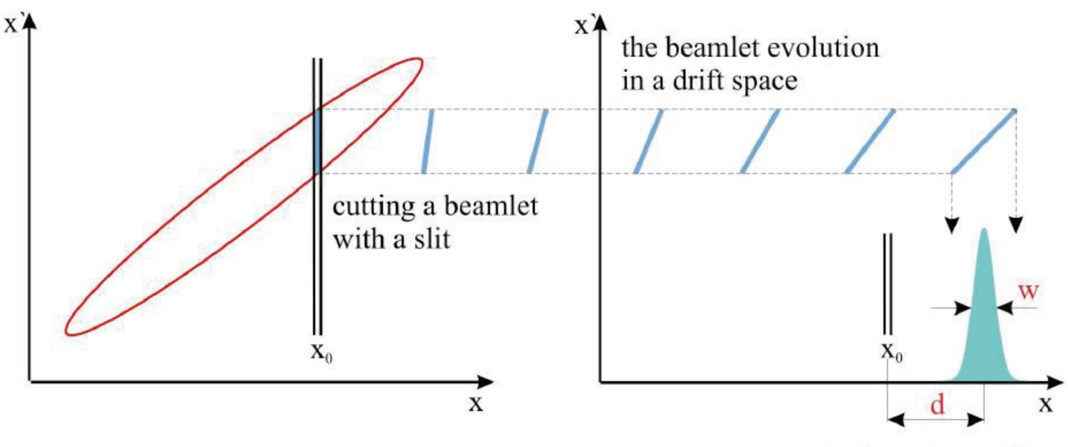


Results – Slit mask

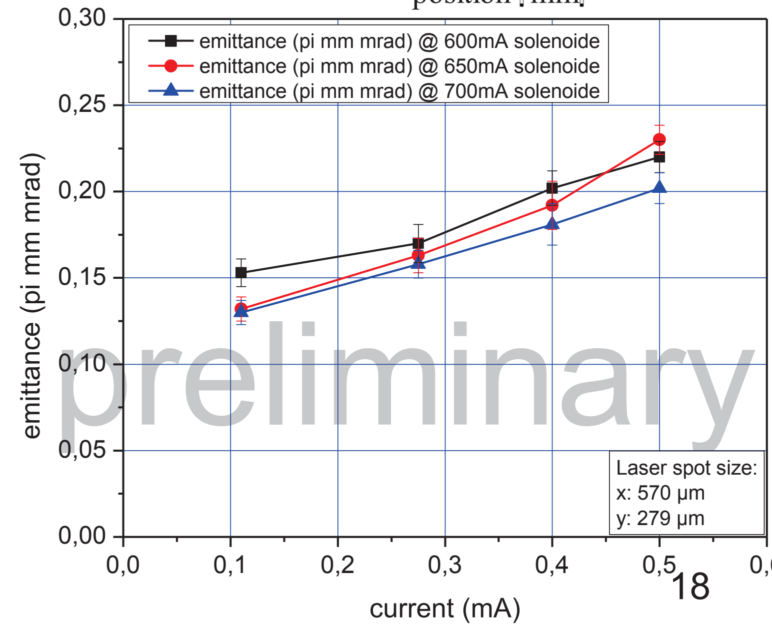








Electron beam diagnostic at the ELBE FEL | P. Evtushenko - 2004



summary & outlook

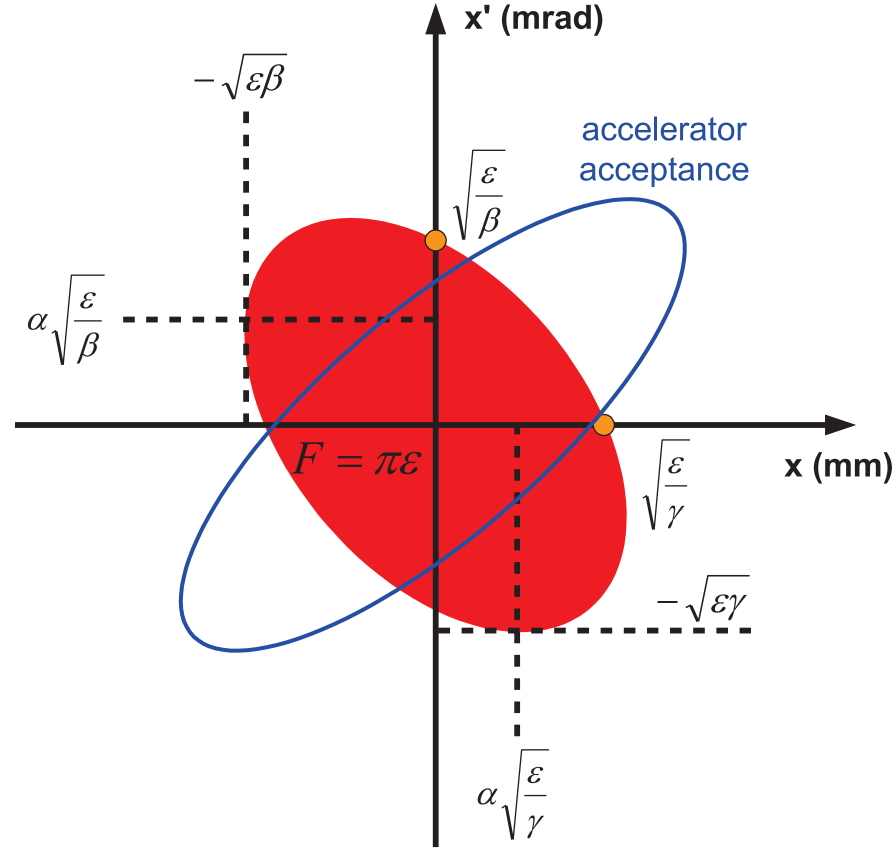
- diagnostic beam line is build up and ready to get used
- possibility to measure the two trans. phase spaces an the temporal distribution for different currents and beam diameter
- cross check between screen, wire and mask measurements
- three available laser wave lengths (405 nm, 520 nm & 780 nm)
- investigations of the beam halo with wires and perforated screens

- get final results for all laser wavelength
- closer look to helicity correlated asymmetries
- characerization if the bunches are suitable for 1 mA/0.8 pC (stage 1)

Thanks for your attention!

Introduction - Emittance

Emittance-ellipse $\gamma x^2 + 2\alpha x x' + \beta x'^2 = \varepsilon$



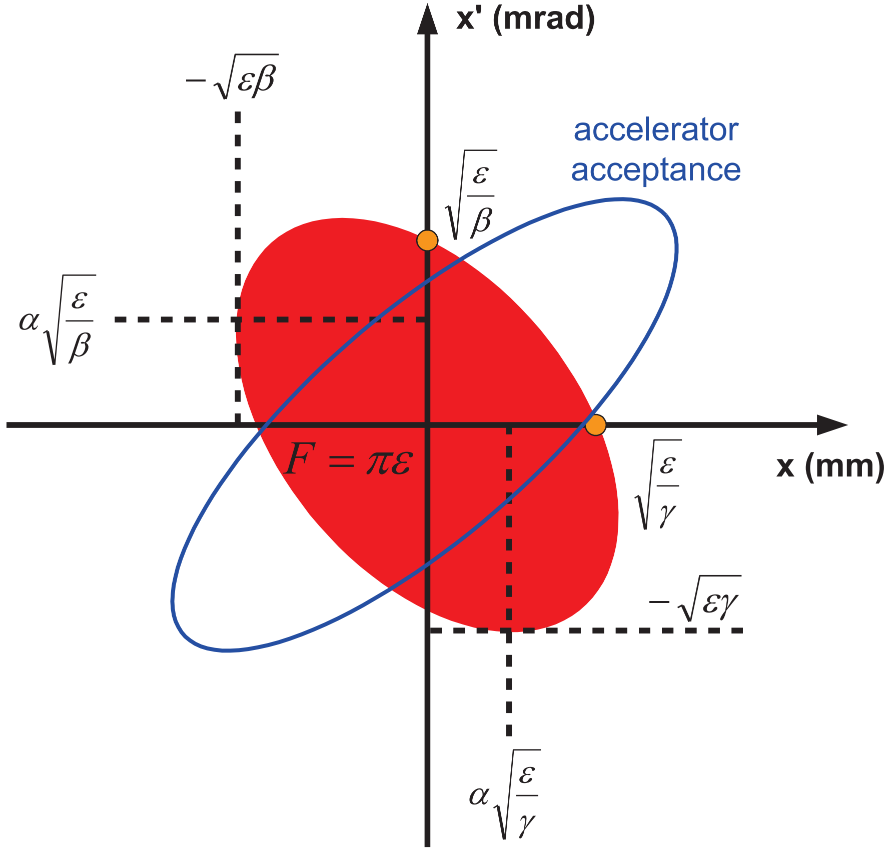
- 6 dimensional phase space
- transversal:
  - displacement and divergence
- longitudinal:
  - phase and energy spread
- TWISS-Parameters:
  - α, β und γ

Introduction - Emittance

Emittance-ellipse $\gamma x^2 + 2\alpha x x' + \beta x'^2 = \varepsilon$

possibilities to measure the emittance

- quadrupole scan (std. technique)
  - measure the beam profiles for different focus strength
- slit or hole mask (new technique in IKPH)
  - measure the position displacement & width of divergence distribution



Backup – Quadrupol-Scan

- beam diameter is linked to the Beta-Matrix

$$r_{rms}^2 = x^2 = \varepsilon\beta = \xi_{11}$$

- Beta-Matrix with TWISS-Parameters

$$M_{Beta} = \begin{pmatrix} \xi_{11} & \xi_{12} \\ \xi_{21} & \xi_{22} \end{pmatrix} = \varepsilon \begin{pmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{pmatrix}$$

- emittance calculation

$$\varepsilon = \sqrt{\det(M_{Beta})} = \sqrt{\xi_{11}\xi_{12} - \xi_{12}^2}$$

- matrices for the drift & quadrupol

$$M_{Drift} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix}$$

$$M_{Quad,-x} = \begin{pmatrix} \cos(\sqrt{k}s) & \frac{1}{\sqrt{k}\sin(\sqrt{k}s)} \\ -\sqrt{k}\sin(\sqrt{k}s) & \cos(\sqrt{k}s) \end{pmatrix}$$

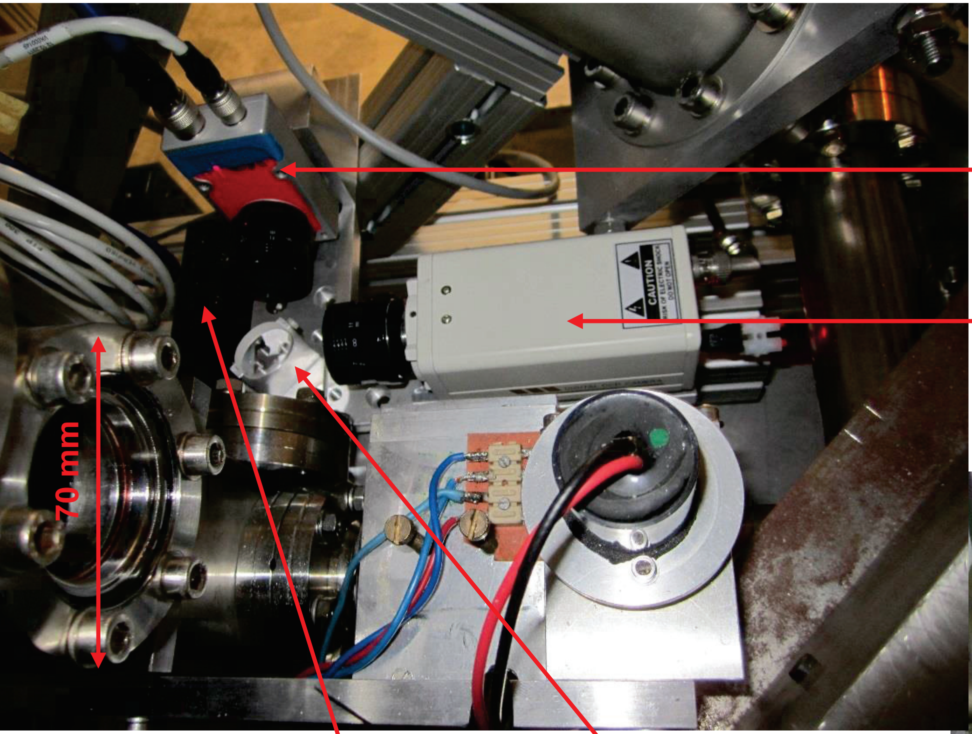
$$M_{Quad,x} = \begin{pmatrix} \cosh(\sqrt{k}s) & \frac{1}{\sqrt{k}\sinh(\sqrt{k}s)} \\ -\sqrt{k}\sinh(\sqrt{k}s) & \cosh(\sqrt{k}s) \end{pmatrix}$$

fit-function for the data of the quadrupol scan

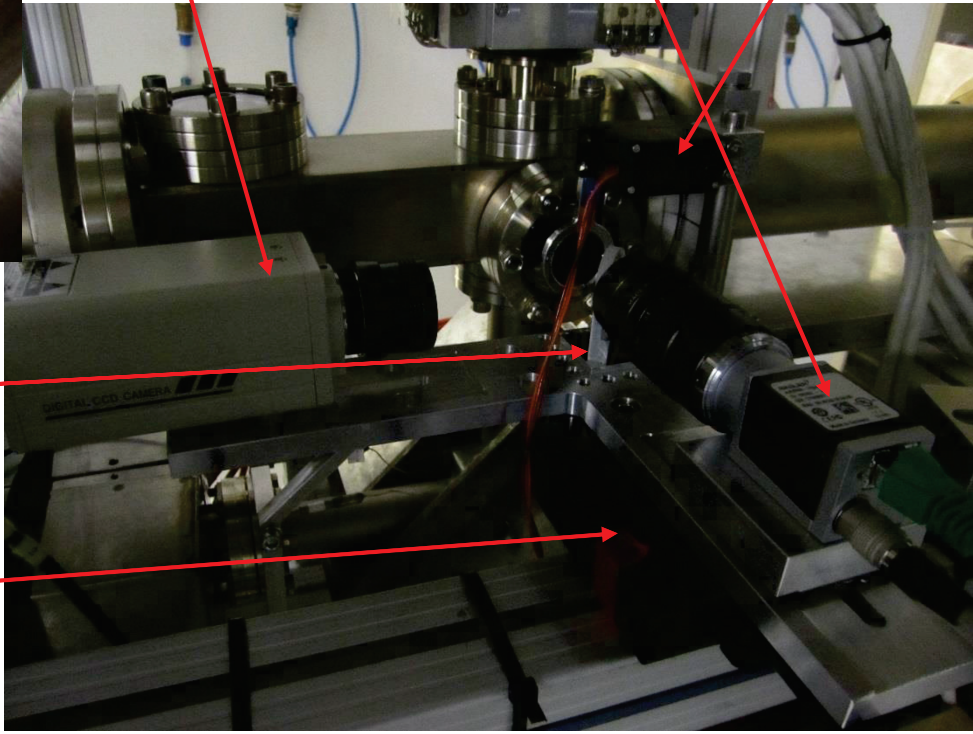
$$r_{rms}^2(k) = \begin{aligned} &\xi_{11}\left(\cos(\sqrt{k}s) - L\sqrt{\tfrac{s}{k}}\sin(\sqrt{k}s)\right)^2 \\ &+ \xi_{22}\left(\sqrt{\tfrac{s}{k}}\sin(\sqrt{k}s) + L\cos(\sqrt{k}s)\right)^2 \\ &+ 2\xi_{12}\left(\sqrt{\tfrac{s}{k}}\sin(\sqrt{k}s) + L\cos(\sqrt{k}s)\right) \\ &\cdot\left(\cos(\sqrt{k}s) - L\sqrt{\tfrac{s}{k}}\sin(\sqrt{k}s)\right) \end{aligned}$$

k	- focus strength
L	- length of the drift
s	- eff. length of the Quad.
α, β und γ	- TWISS-Parameter
ε	- emittance

Backup – Quadrupol-Scan



Scanner 2



digital camera

analog camera

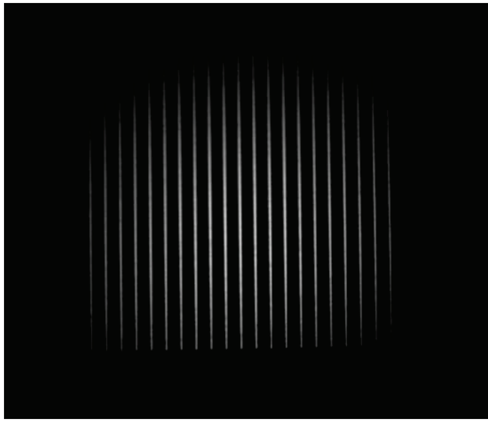
attenuator

beam splitter 50:50

translation table 25 mm way

Scanner 1

Backup – Slit mask



- Example for a slit mask measurement
  - Fit function contains a sum of Gauss functions

$$F_{Fit}(x) = \sum_i \frac{A_i}{\sigma_i\sqrt{2\pi}} \exp\left(-\frac{x - x_{0i}}{\sigma_i\sqrt{2}}\right)^2$$

  - elements of the Beta-Matrix

$$\xi_{11} = \sum_i x_i^2 w_i$$ RMS-beam width

$$\xi_{22} = \sum_i x_i w_i \frac{x_{0i} - \langle x_0 \rangle - x_i}{L}$$ correlated und uncorrelated beam divergence

$$\xi_{12} = \sum_i w_i \frac{\sigma_i^2 + \left(x_{0i} - \langle x_0 \rangle - x_i\right)^2}{L^2}$$ correlation between beam width & divergence

  - calculation of the emittance

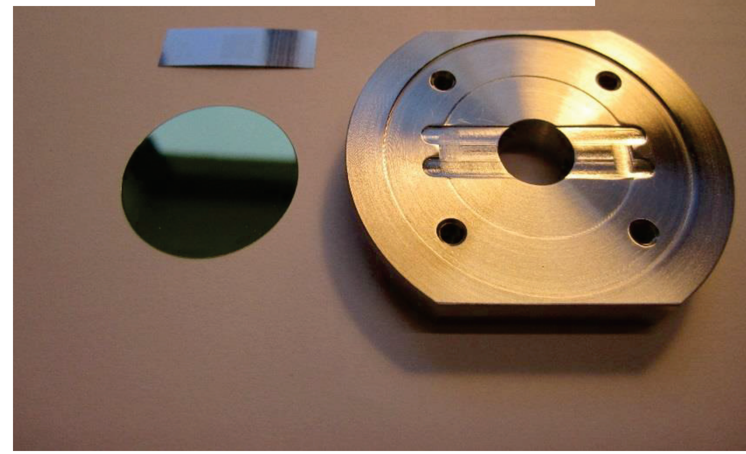
$$\varepsilon_{RMS} = \frac{1}{L}\sqrt{\left(\sum_i x_i^2 w_i\right)\left(\sum_i w_i\left(\sigma_i^2 + \left(x_{0i} - \langle x_0 \rangle - x_i\right)^2\right)\right) - \left(\sum_i x_i w_i \left(x_{0i} - \langle x_0 \rangle - x_i\right)\right)^2}$$

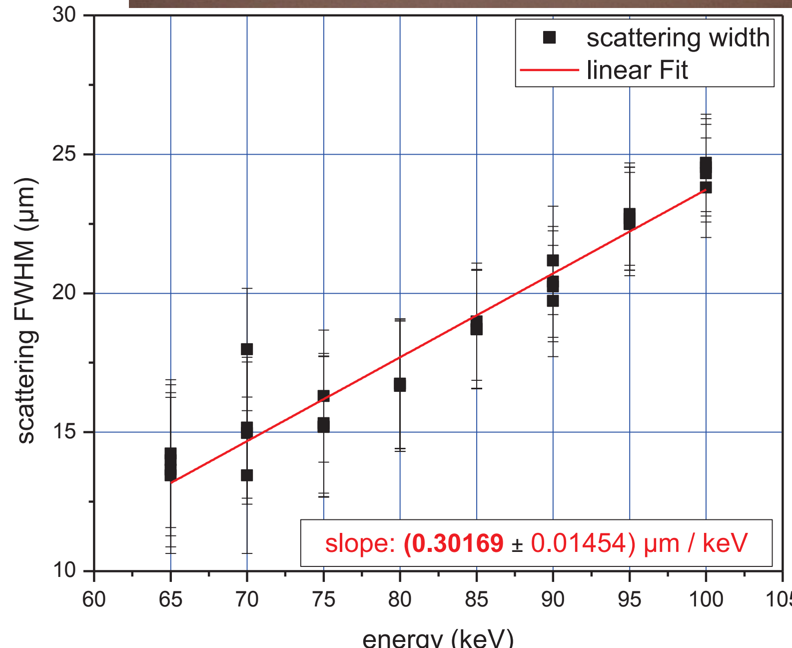
Backup – Scattering in Ce:YAG

- Scattering width ≈ penetration depth
- penetration depth
  - Bethe-Bloch < 48 µm
  - „GEANT 4“ < 45 µm
  - „Casino“ < 30 µm
  - Crytur Inc. 38 µm

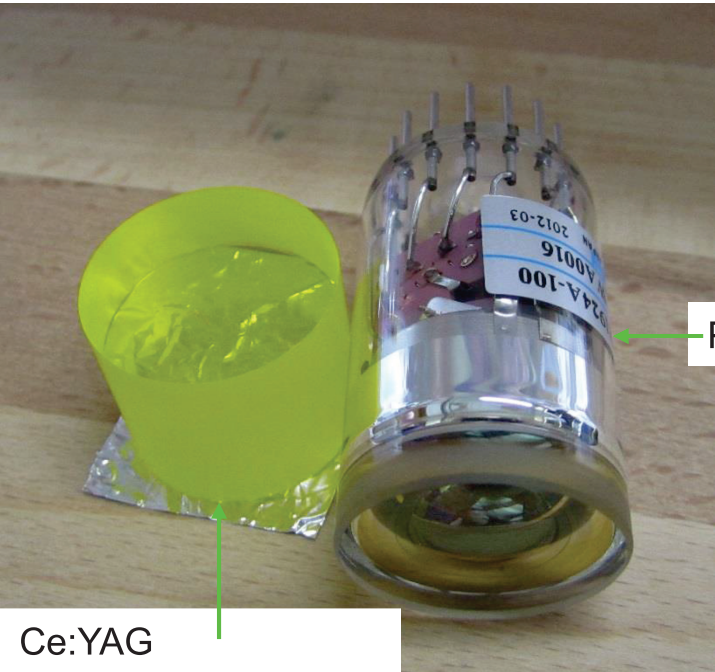
- first estimation: scattering is bigger than the hole diameter (25 µm)

holder for investigations of the electron scattering in YAG





Backup - γ detektor



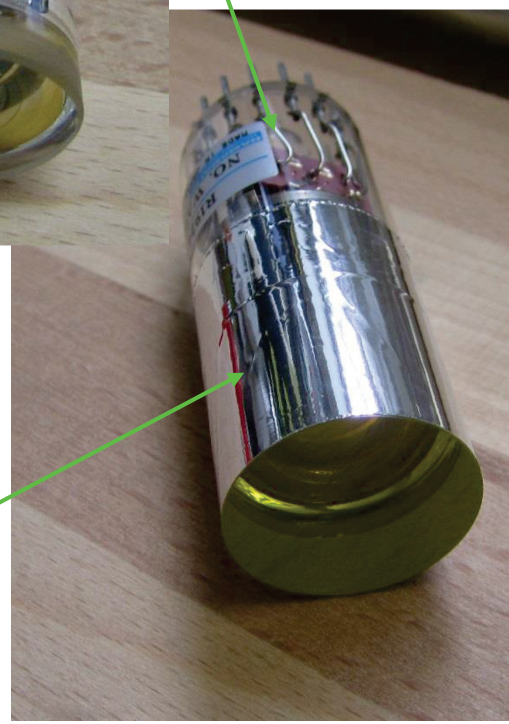
PMT

Ce:YAG

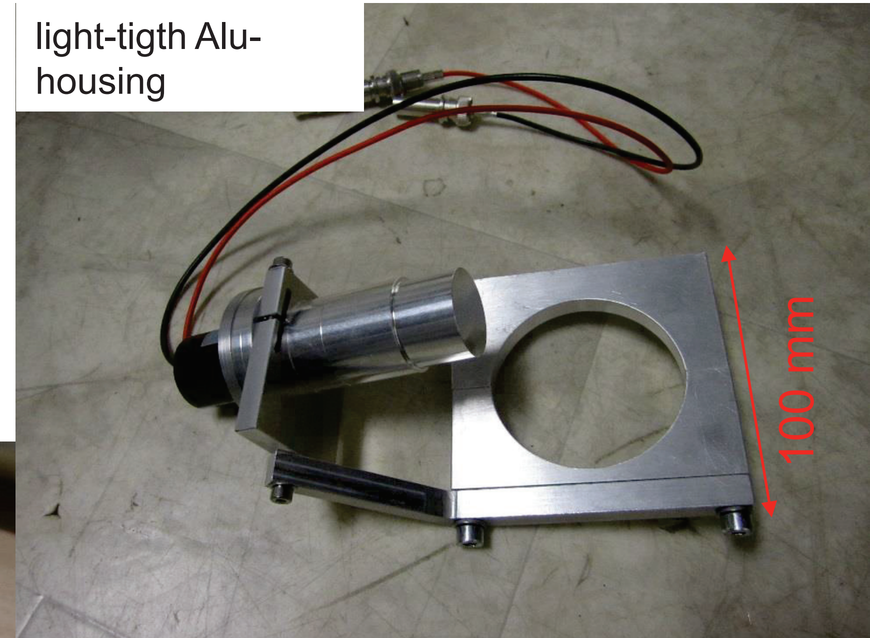
25 mm diameter

20 mm higth

reflective foile



light-tigth Alu-housing

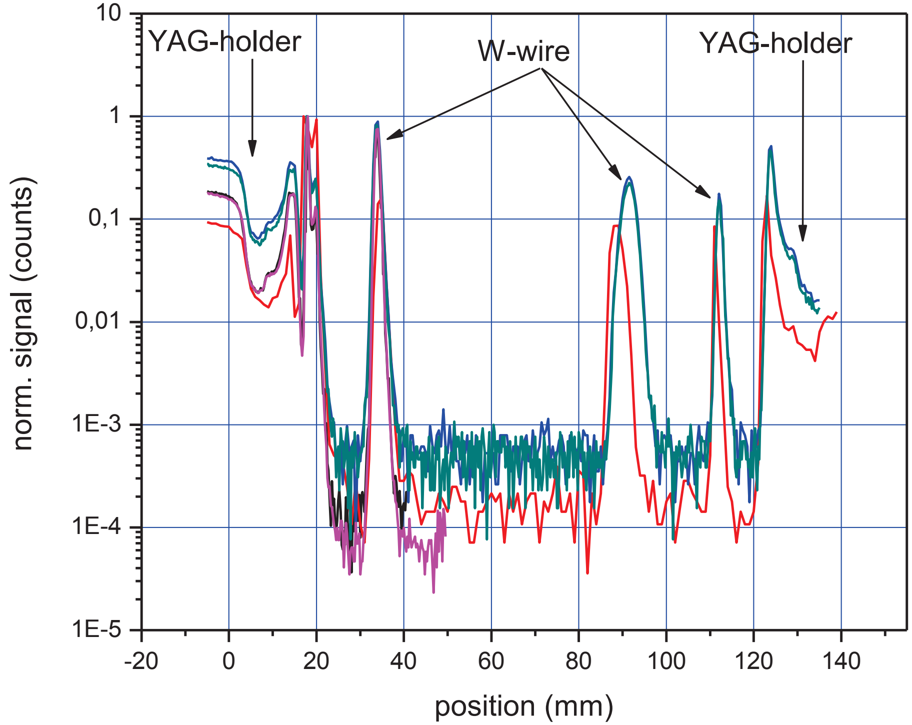


mounted on Scanner 1

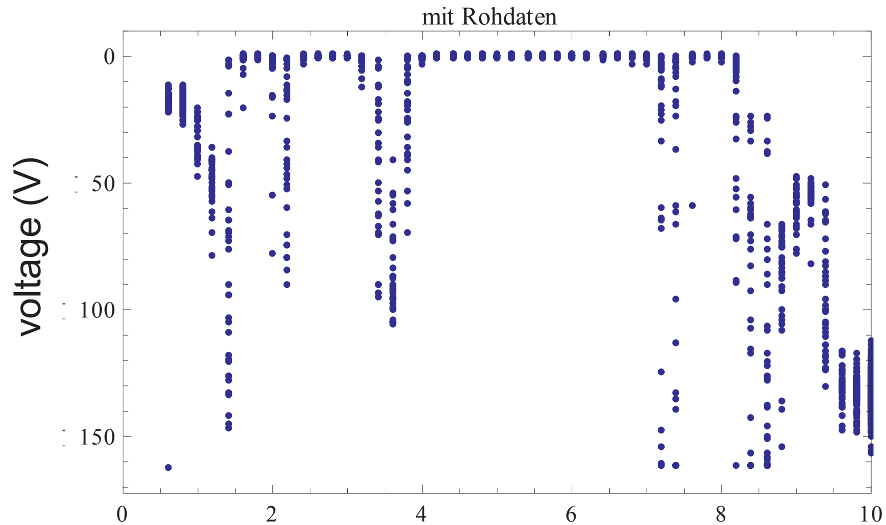
Backup - γ detektor

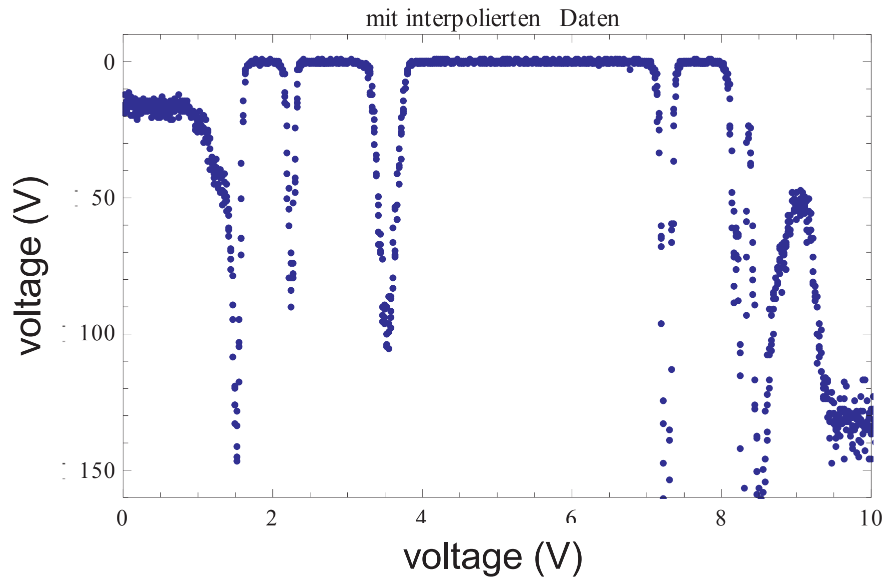
- investigation of the beam halo
- quadrupol-scan
- helicity correlated asymmetries
- high dynamic range of $10^3 – 10^4$

with MOPL-Programm

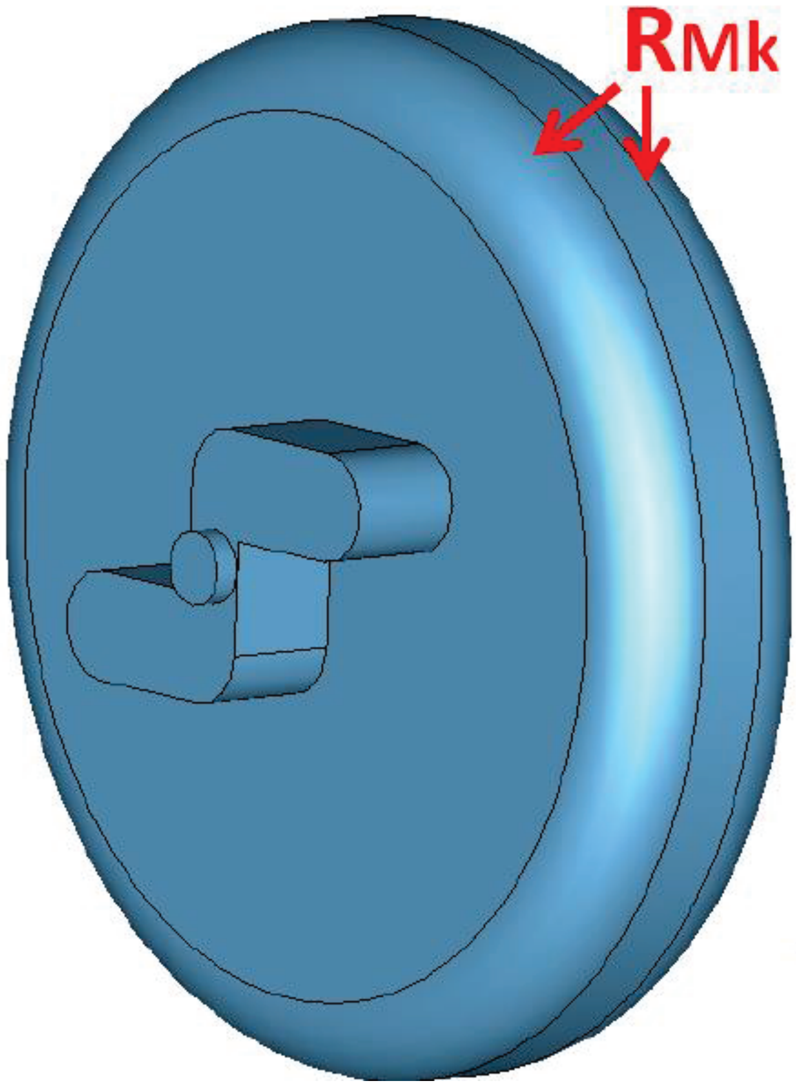


with Scanner-Kiste & Oszi



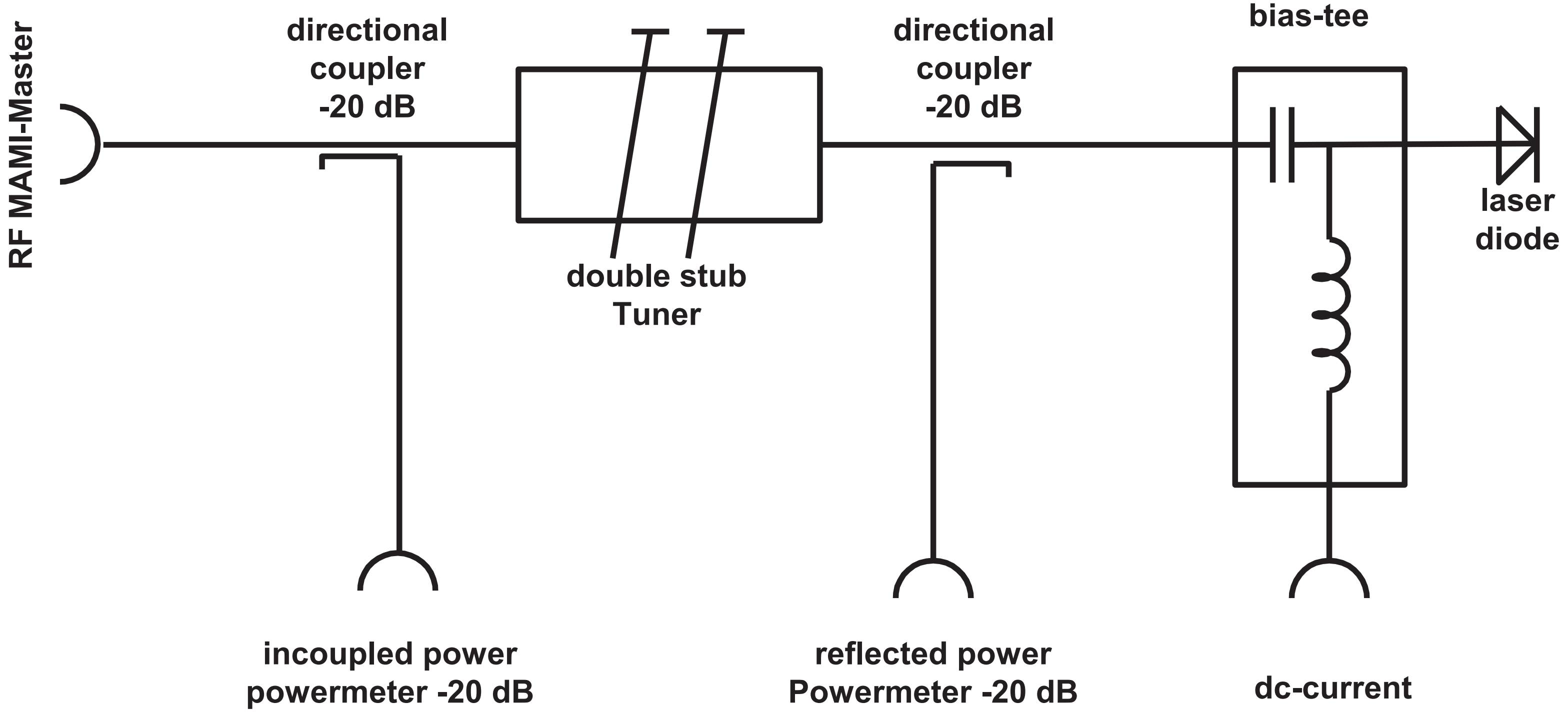


Backup – Deflecting cavity

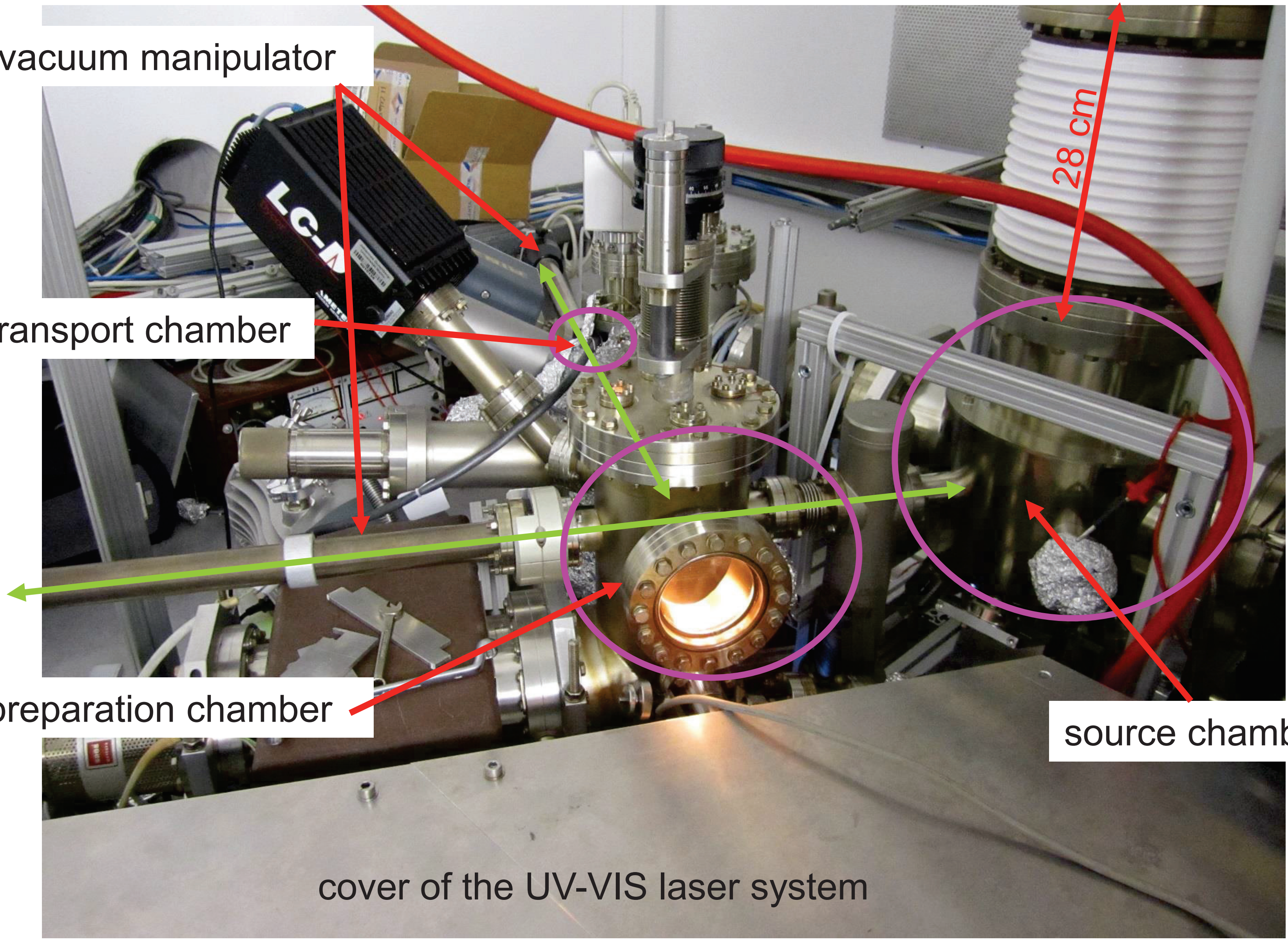


Diploma thesis: V. Bechthold

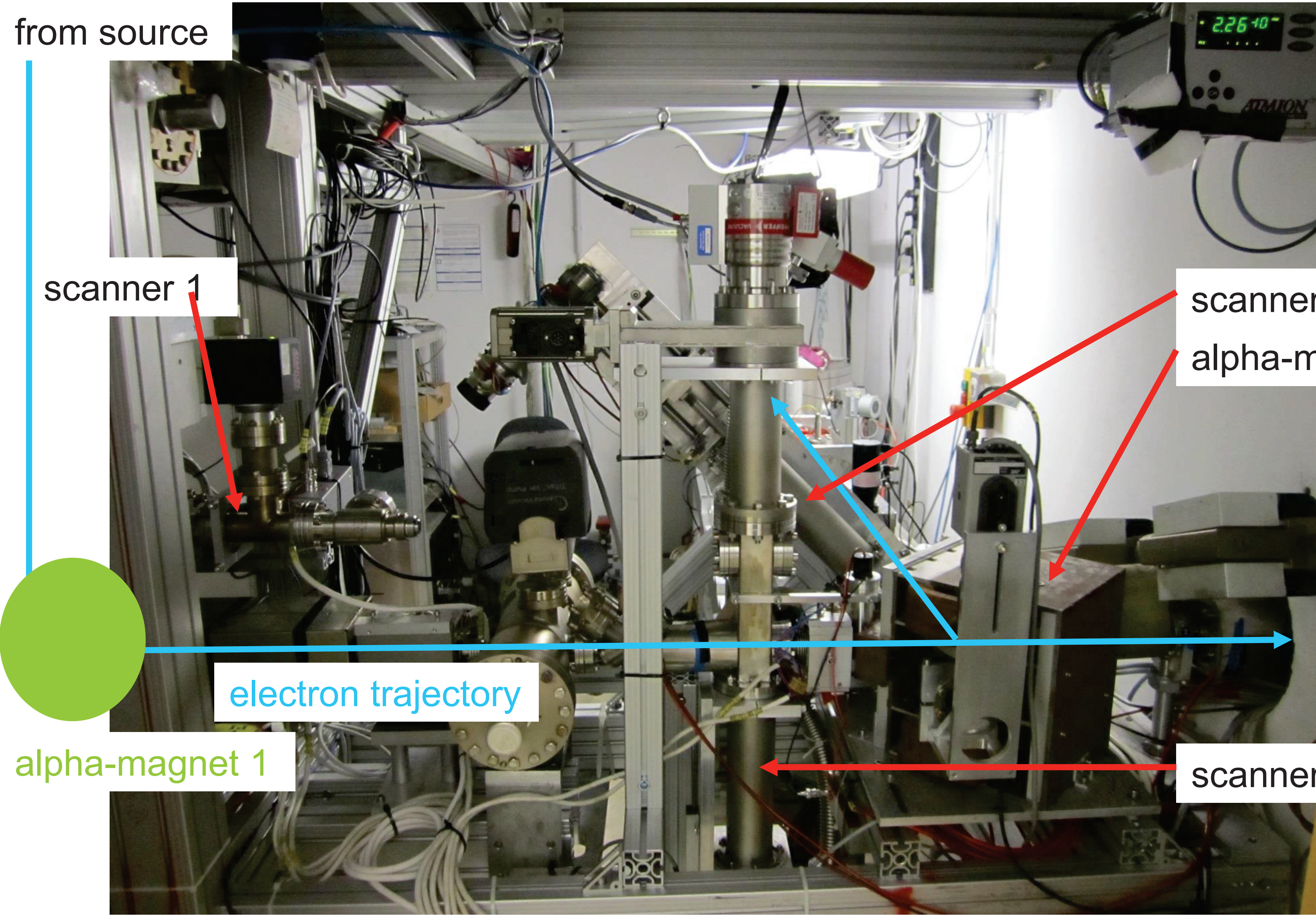
Backup – UV-VIS laser system



Components - Source

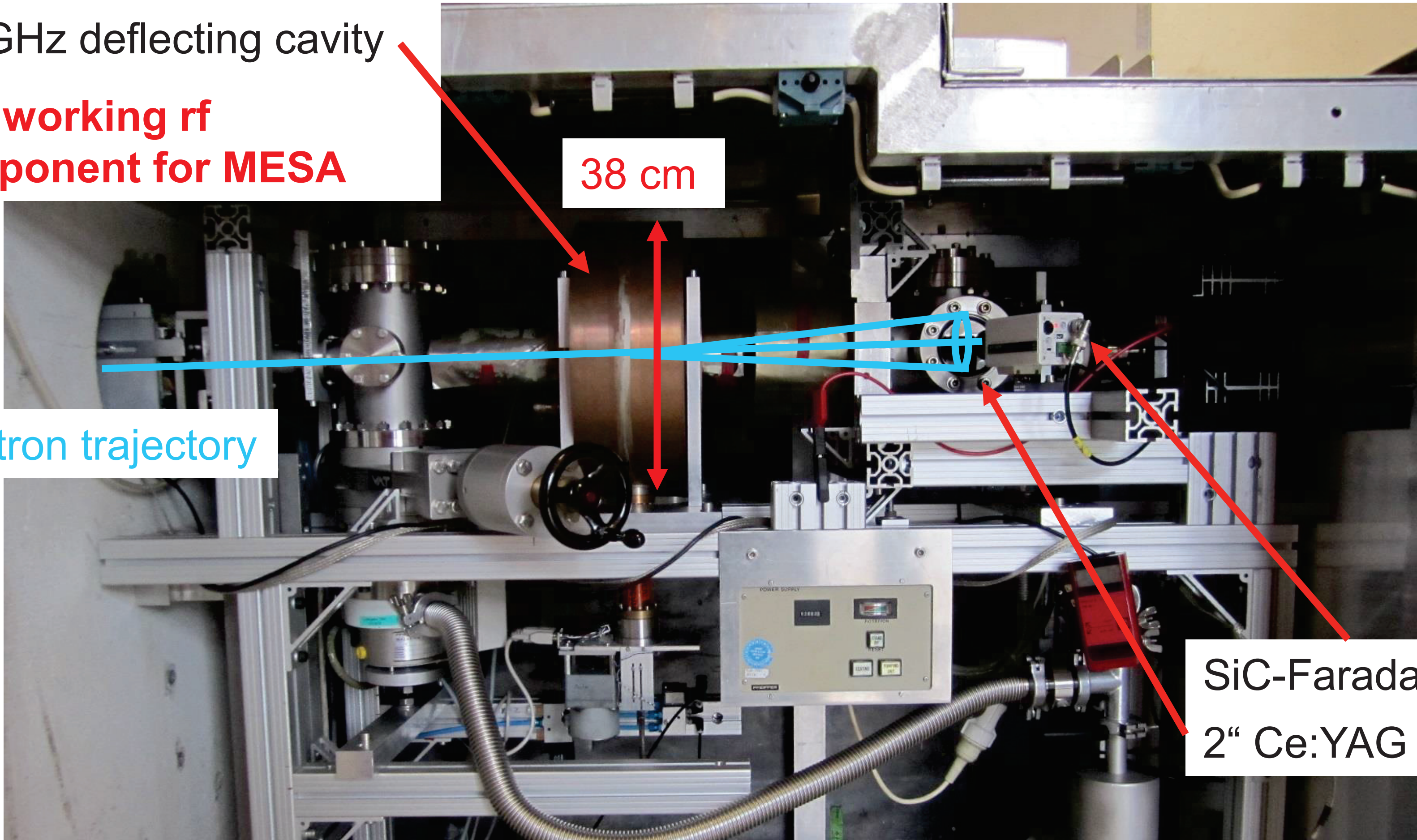


Components - Source



Components – Deflecting cavity

first working rf component for MESA

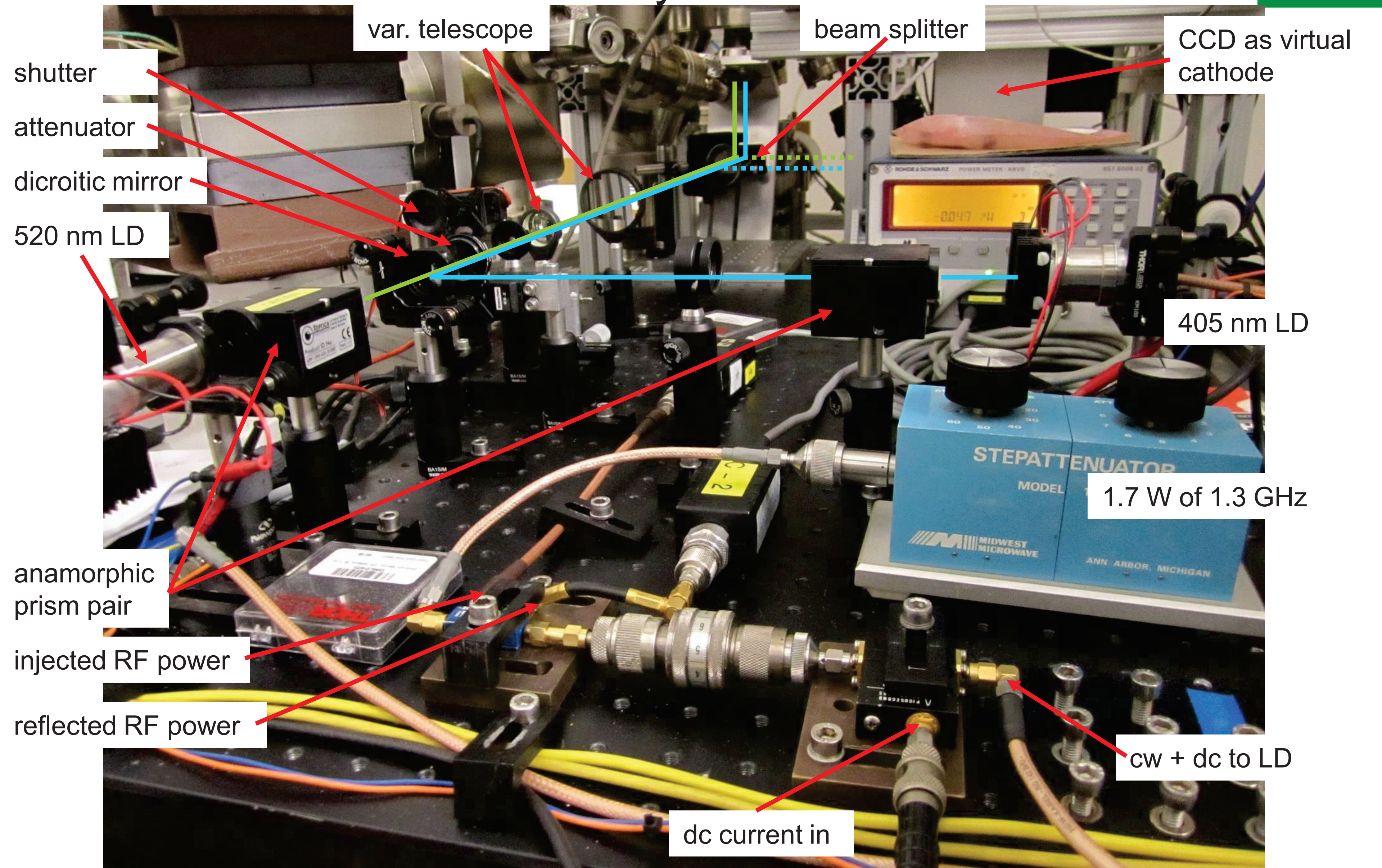


beam line was build up with:

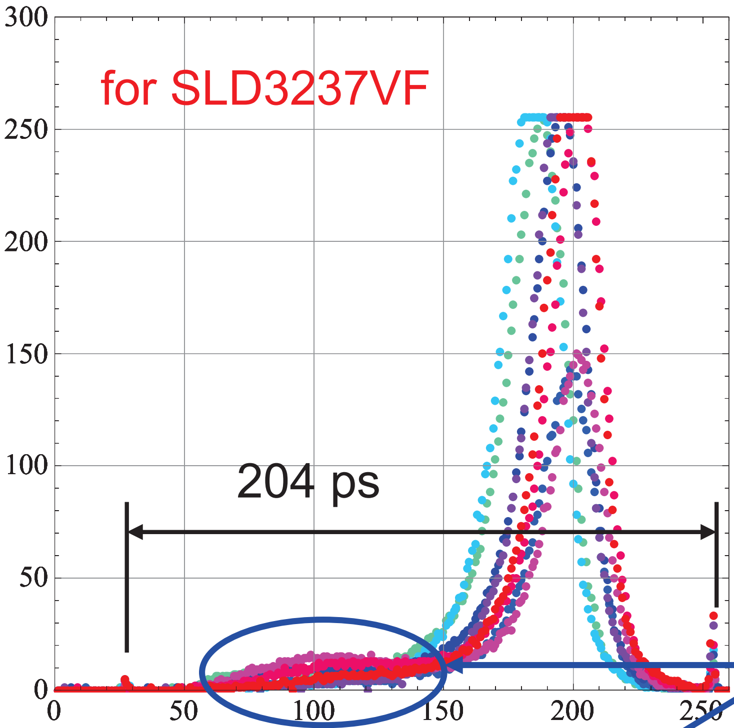
V. Bechthold (diploma thesis)

B. Ledroit (bachelor thesis)

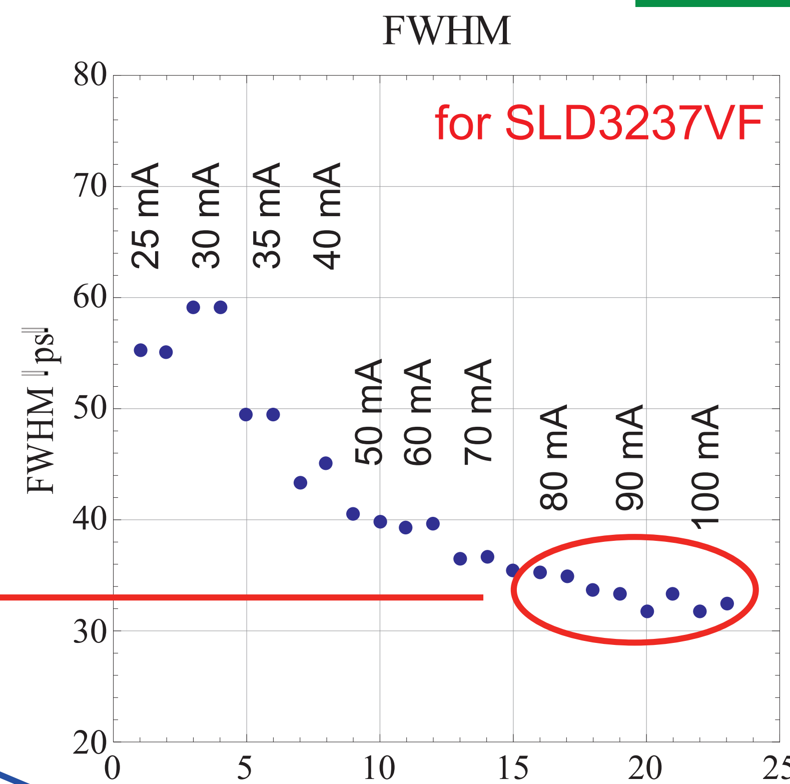
Components
UV-VIS laser system



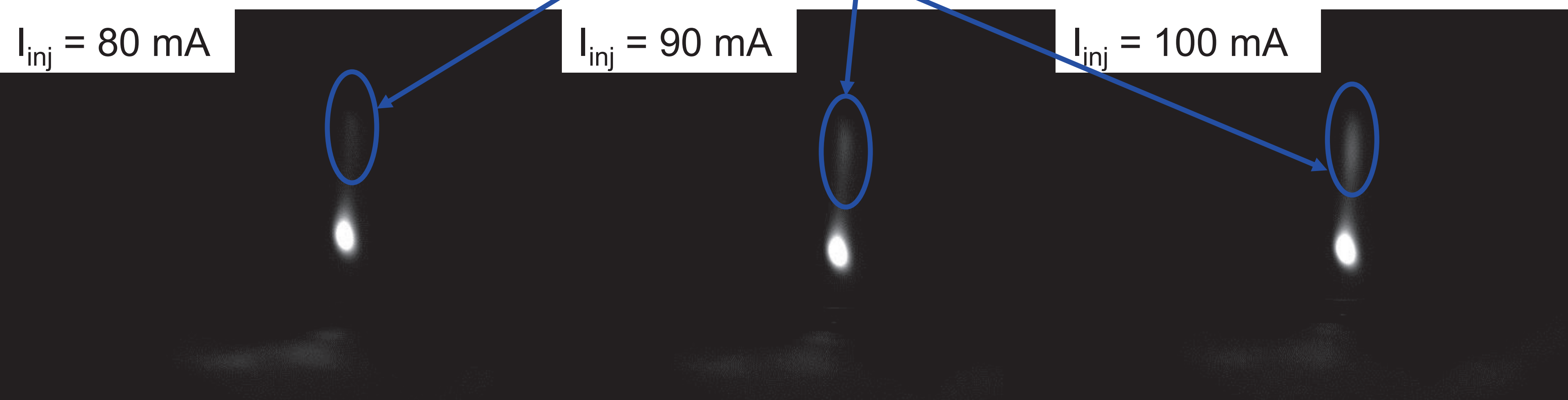
Components
UV-VIS laser system



measurement with lin. defl. cavity @ 2.45 GHz

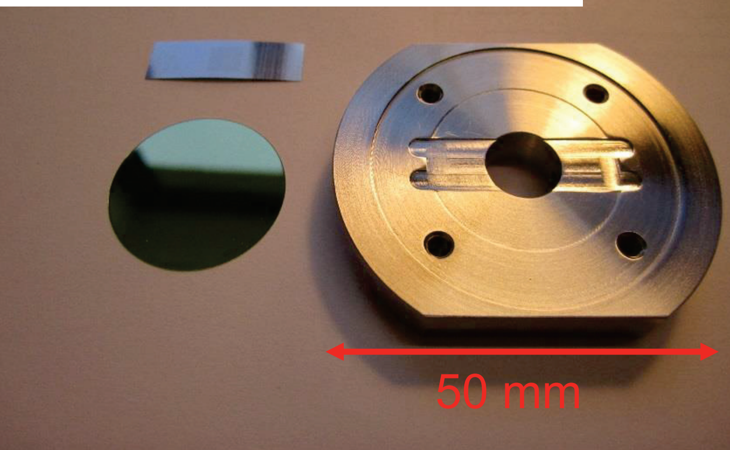


unwanted beam - tail



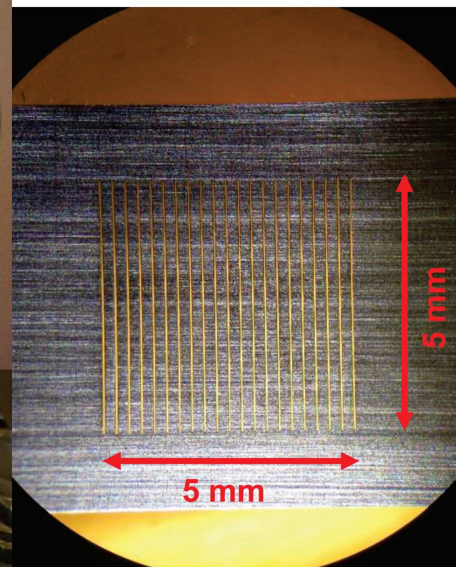
Components - Scanner

holder for investigations of the electron scattering in YAG



carriage of Scanner 3

slit mask



slit width 25 µm

slit distance 250 µm

number of slits 21

area 5x5 mm²

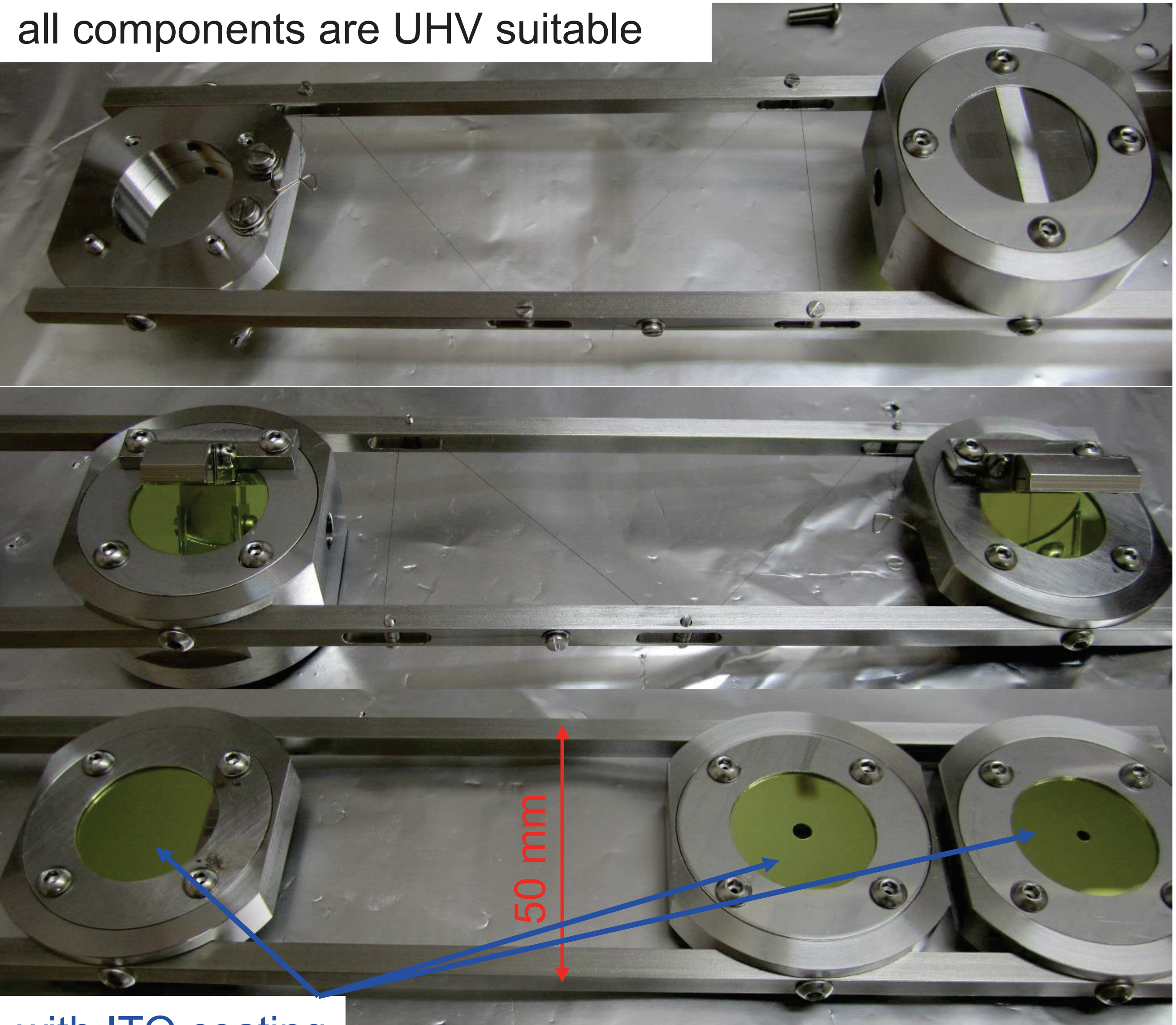
50 µm stainless steel

holder for YAG-screens

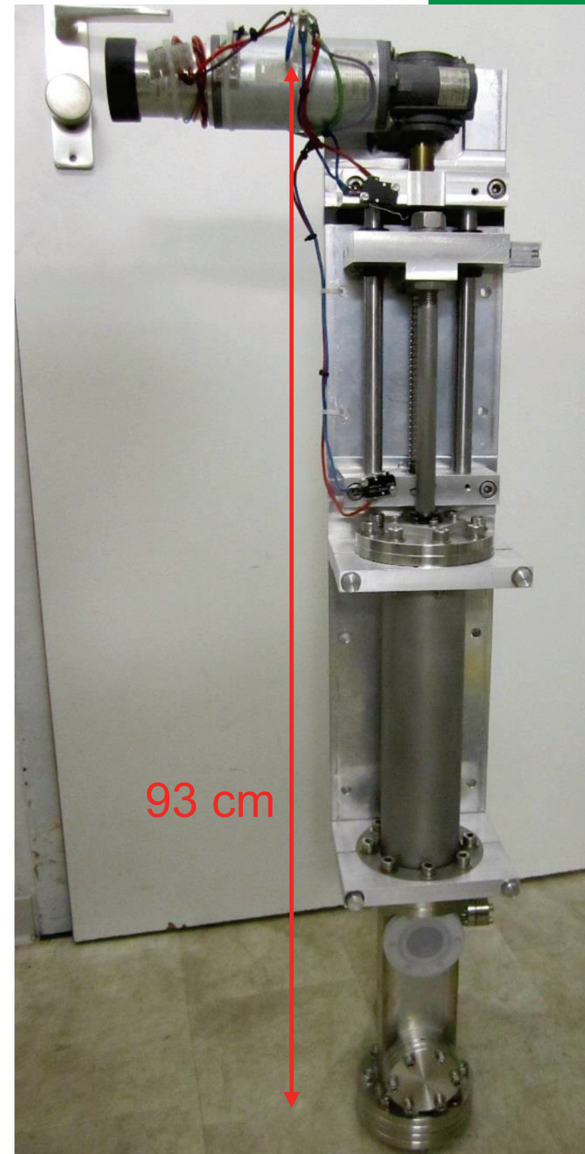
mounted YAG-sceens

Components - Scanner

all components are UHV suitable



with ITO coating

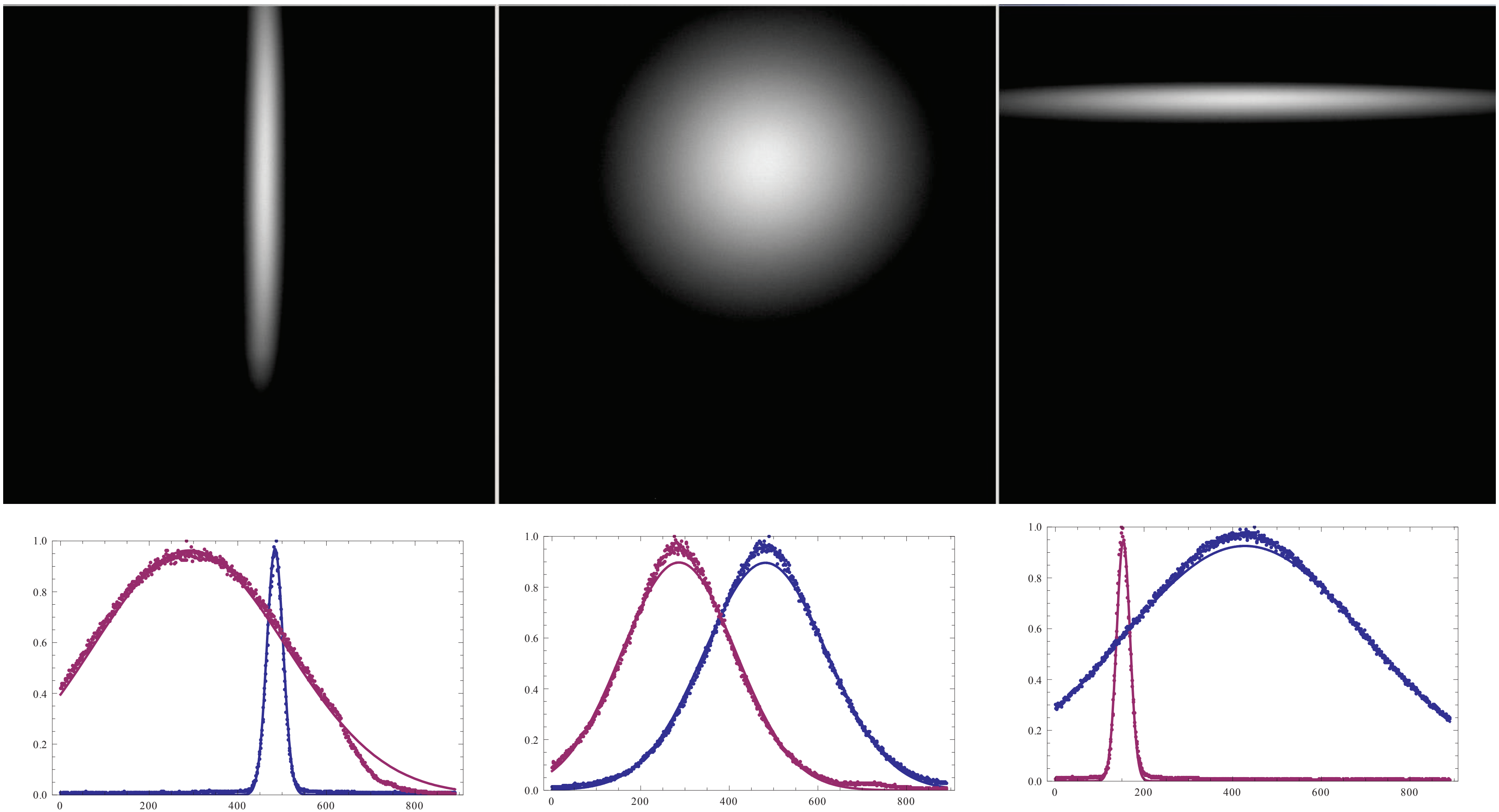


Results – Quadrupol-Scan

focus stregth: 2.75 diopter

focus stregth: 0 diopter

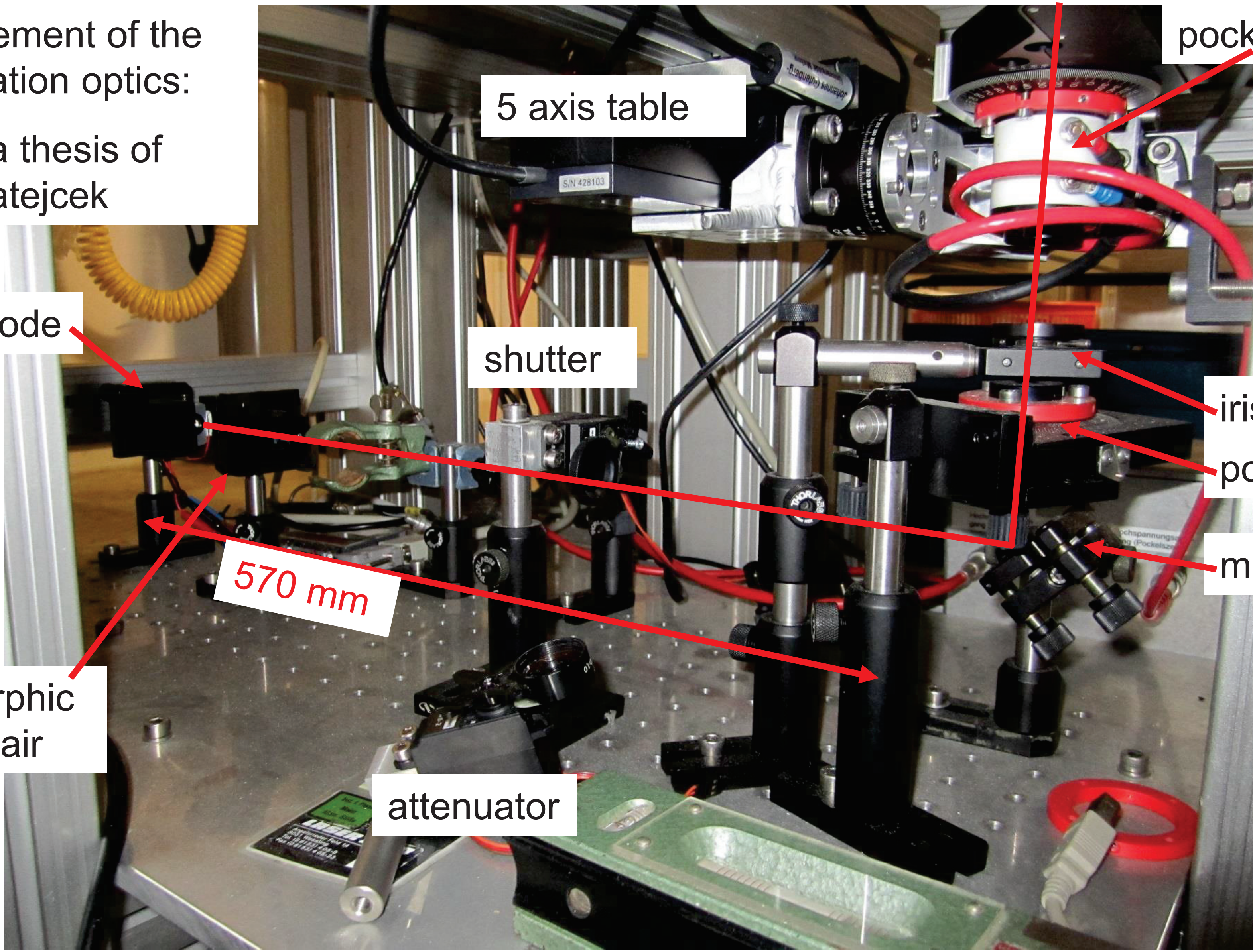
focus stregth: -2.75 diopter



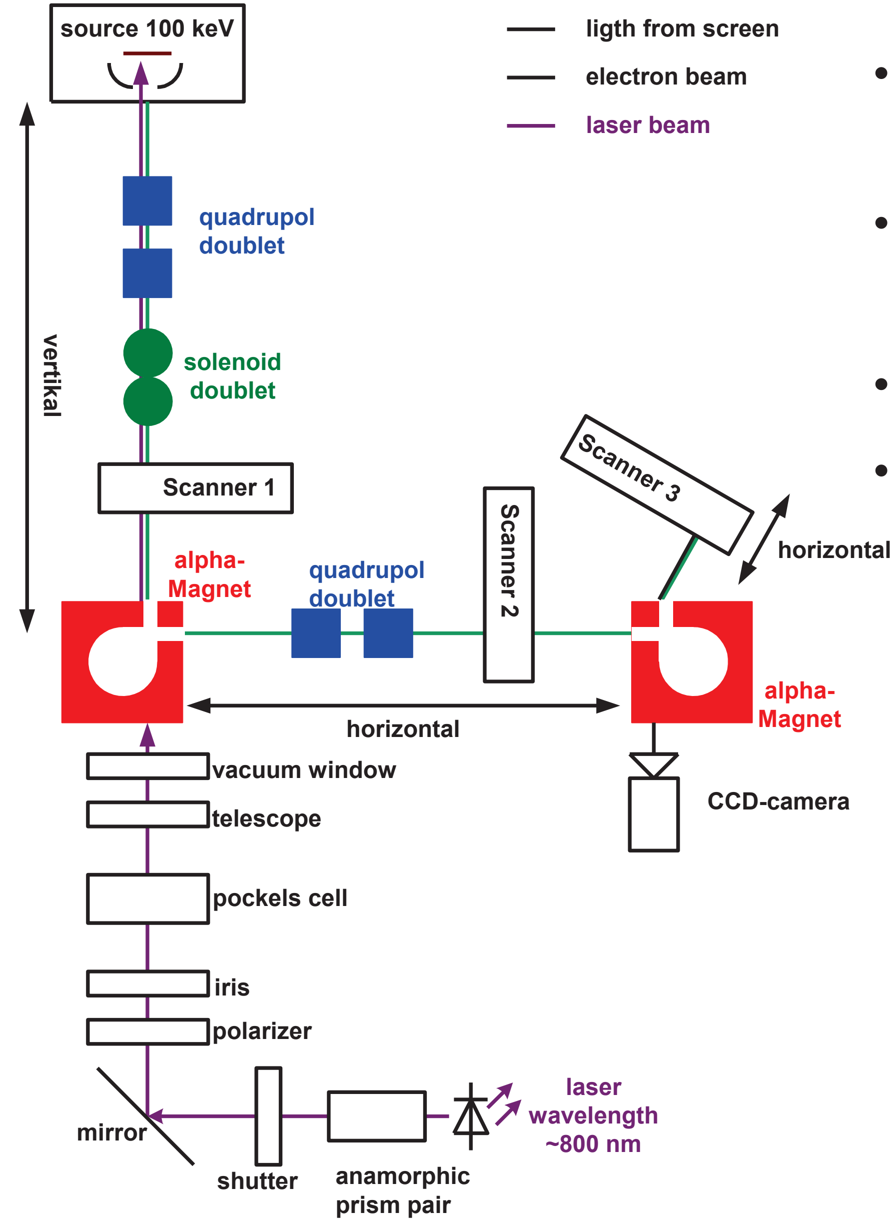
Components – IR laser system

improvement of the polarization optics:

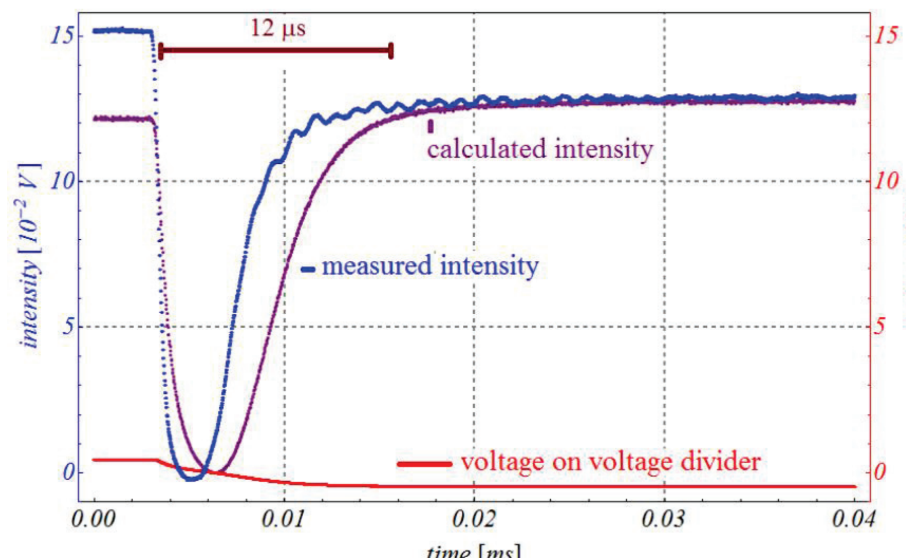
diploma thesis of Chr. Matejcek



Results – IR laser system



- Investigations on helicity correlated asymmetries for P2 experiment
- switching helicity with 1 kHz instead of 50 Hz with RTP pockels cell
- circular polarisation of 99.99%
- loss 1.2% of measurement periode



Diploma thesis: Chr. Matejcek

RTP: rubidium titanyl phosphate - $RbTiOPO_4$