FACULTY OF NUCLEAR SCIENCES AND
PHYSICAL ENGINEERING
Czech Technical University in Prague

Electrical and Optical Diagnostics of Polyacetal Capillary Discharge

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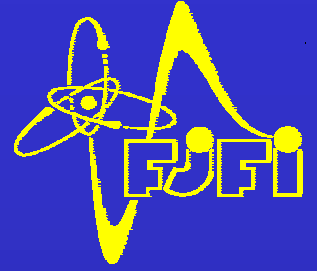
Electrical and Optical Diagnostics of Polyacetal Capillary Discharge

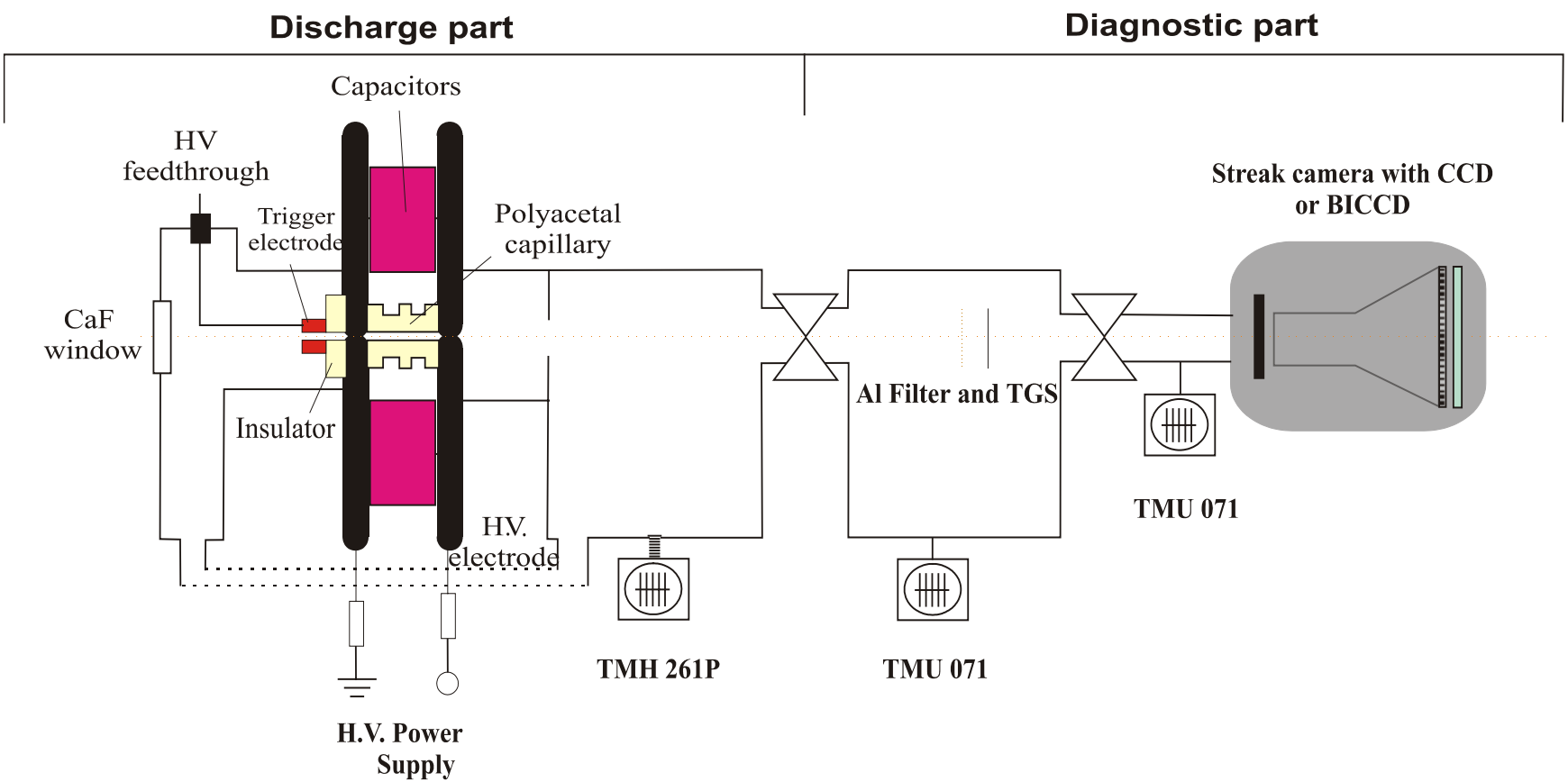


The aim of our work was to build a system to study ablative capillary discharge in 25 mm long polyacetal capillary of various diameters.

Electrical and Optical Diagnostics...

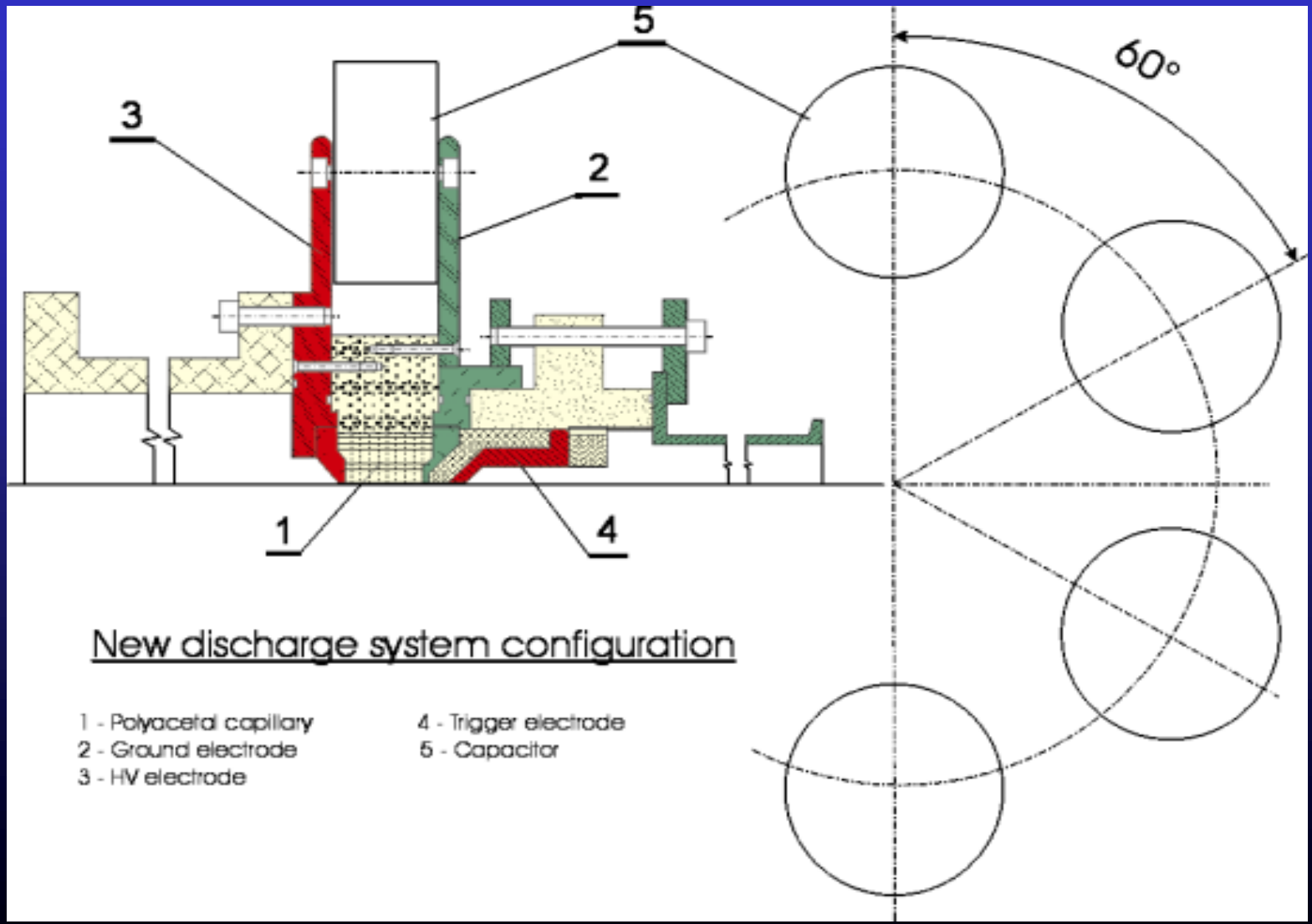
Experimental Setup

Experimental Setup Drawing



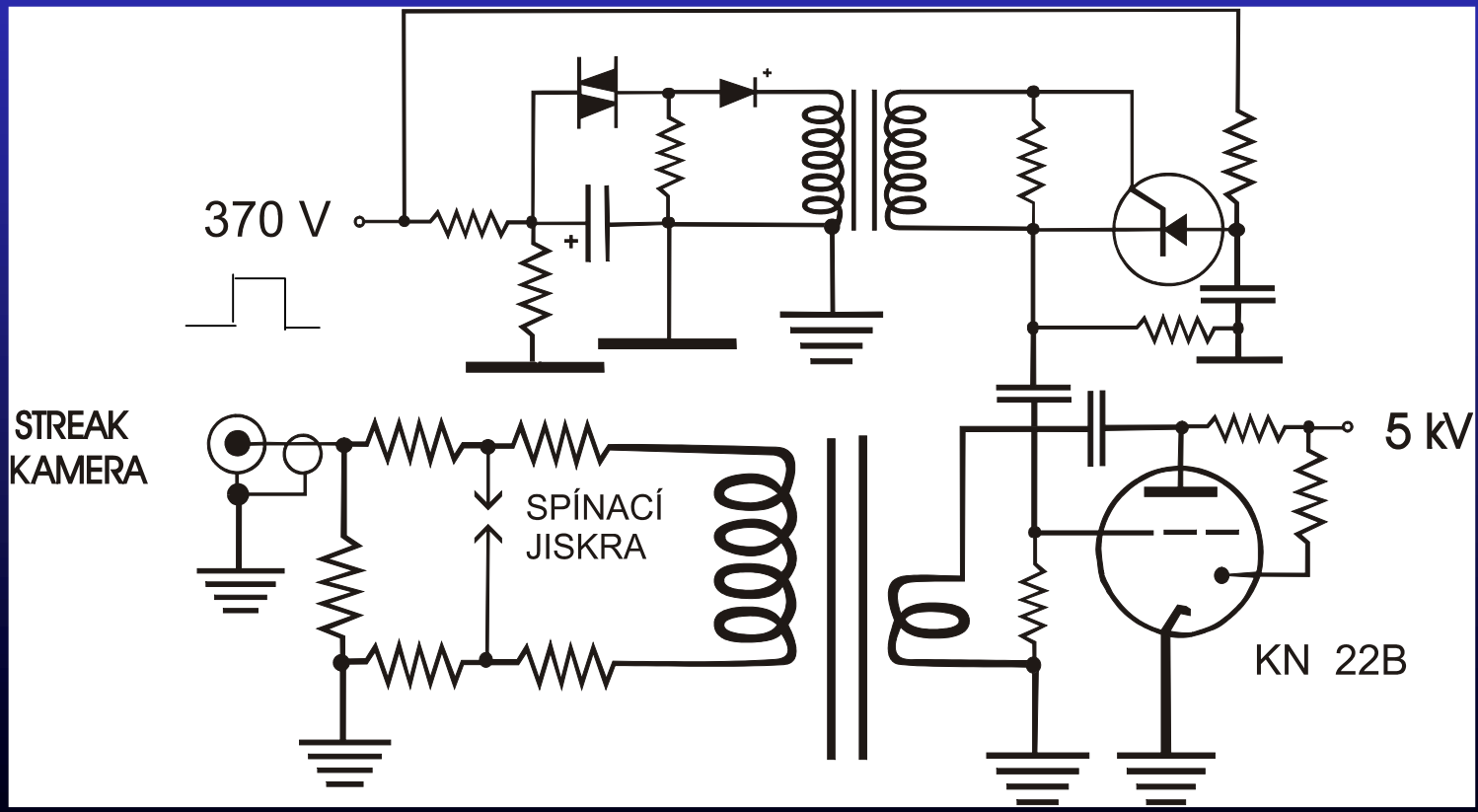
Electrical and Optical Diagnostics...

Experimental Setup



Electrical and Optical Diagnostics...

Experimental Setup



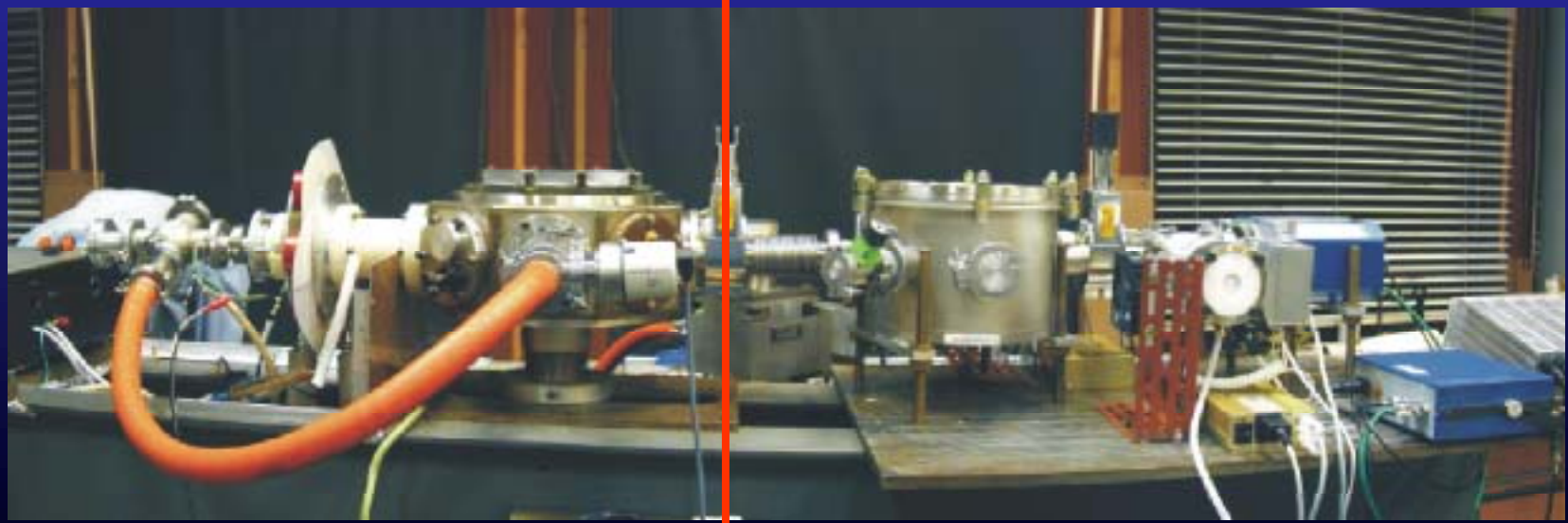
Electrical and Optical Diagnostics...

Experimental Setup

Experimental Setup

Discharge Part

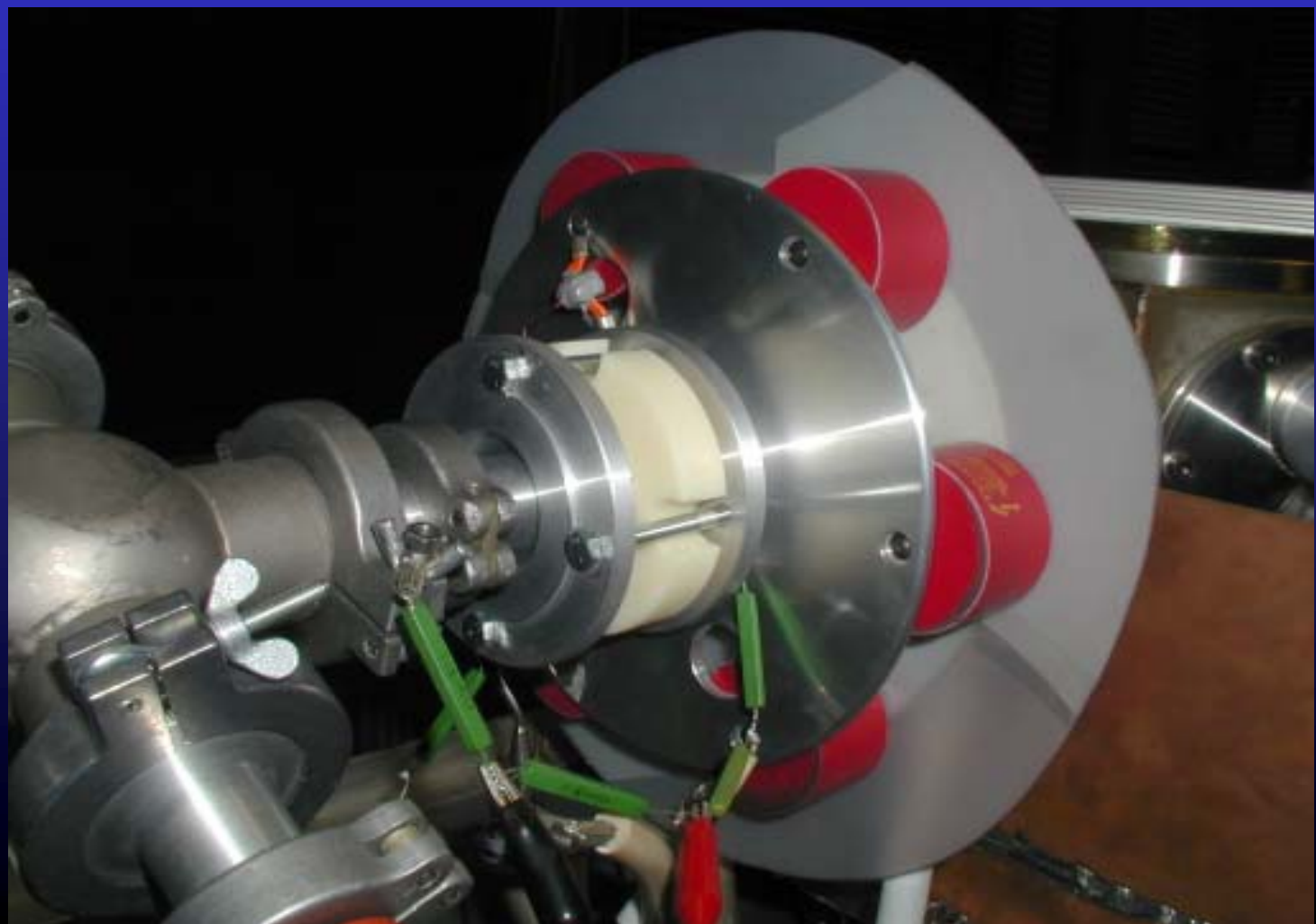
Diagnostics Part



Electrical and Optical Diagnostics...

Experimental Setup

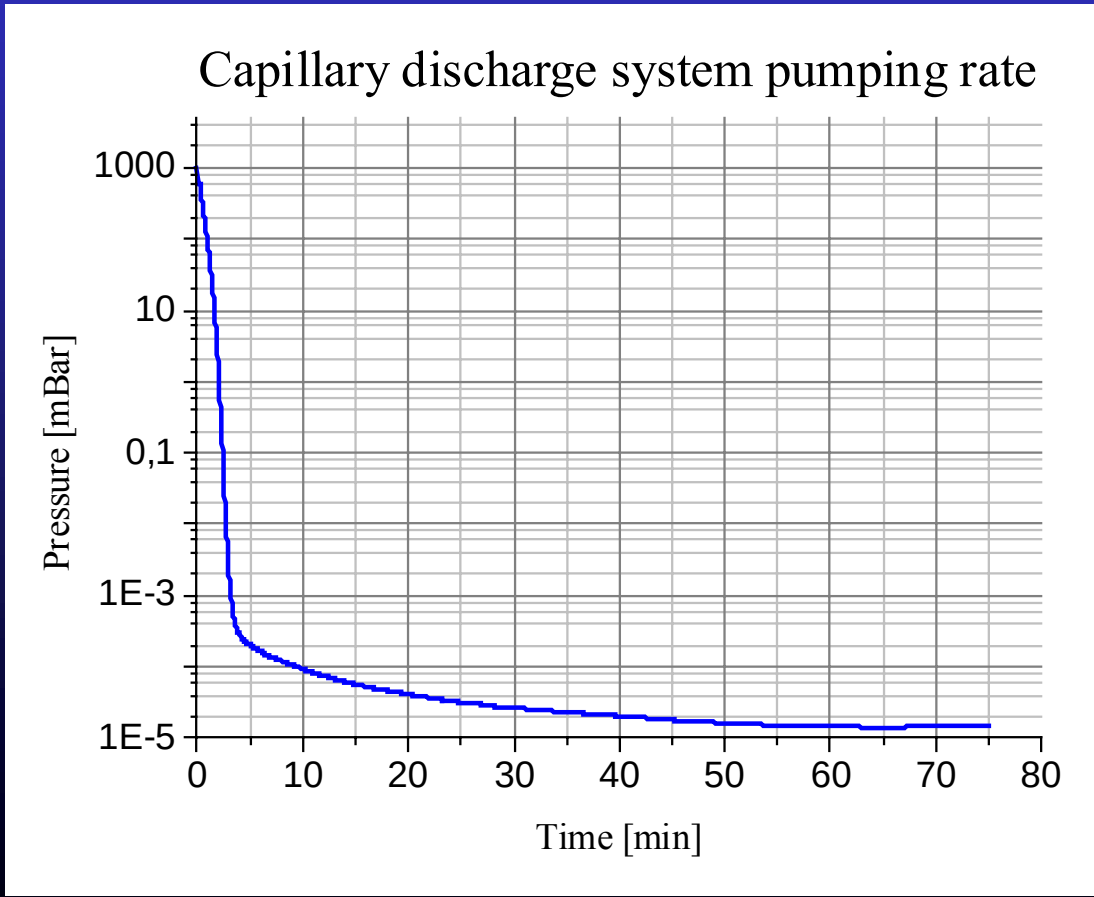
Discharge Part



Electrical and Optical Diagnostics…

Experimental Setup

Probability higher than 1/10 for 40 kV self-breakdown voltage was achieved and the open-end streak camera manufacturer's request of limit working pressure 5.10^{-5} mbar was fulfilled.



Electrical and Optical Diagnostics…

Experimental Setup

Experimental Setup Basic Parameters

Length of capillary	Max. 25 mm
Diameter of capillary	Max. 9 mm
Capacitors	Max. 6x2,5 nF
Working pressure	$5x10^{-5}$ mbar
Voltage between electrodes	Max. +/- 45 kV

Electrical and Optical Diagnostics...

Our next aim was to:

1. Determine the time shape of voltage and current pulse during a triggered electrical discharge in the capillary of various diameters

2. Carry out a streak camera sweep - rate calibration

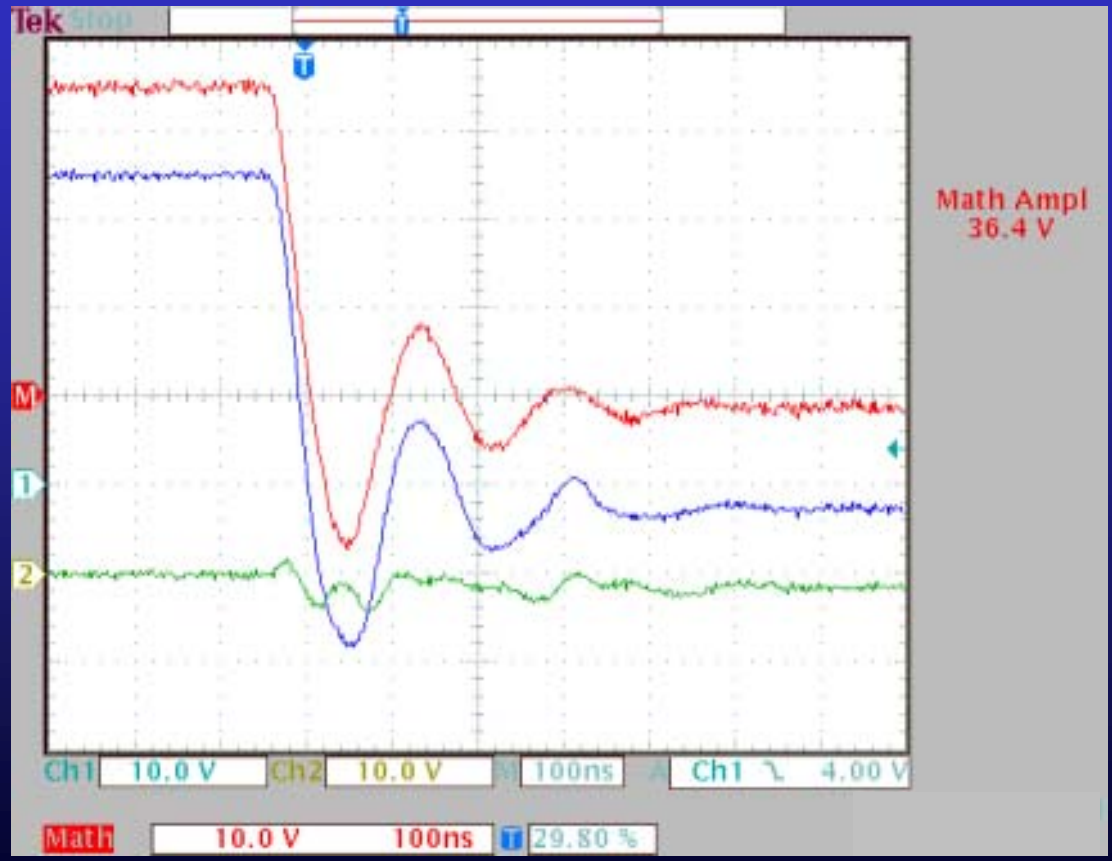
3. Measure the capillary discharge radiation

Electrical and Optical Diagnostics...

Voltage and current determination

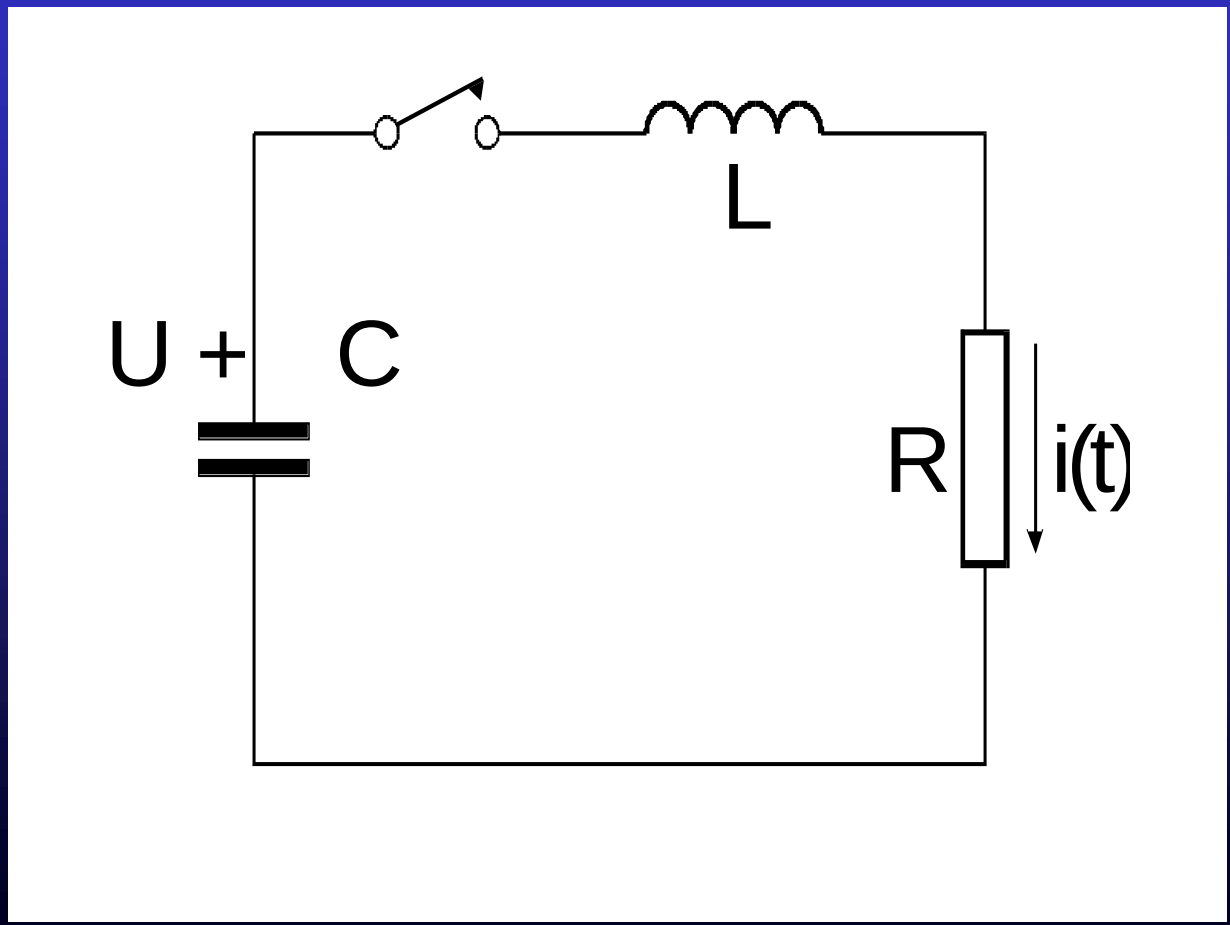
Two high voltage probes TEKTRONIX P6015A meassuring differentially voltage on HV and low voltage electrode with two channel digital scope TEKTRONIX 3032 with 300 MHz bandwith and 2,5 Gsample/s providing substraction.

M = 1 - 2



Electrical and Optical Diagnostics...

Voltage and current determination



Electrical and Optical Diagnostics...

Voltage and current determination

Underdumped *RLC* circuit

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{q}{C}=0$$

$$U=U_0e^{-\gamma_R t}\left(\frac{\gamma_R}{\omega_1}\sin\omega_1 t+\cos\omega_1 t\right)$$

$$q(0)=U_0C \text{ a } I(0)=0$$

$$\gamma_R=R/2L,\omega_1=\sqrt{\omega_0^2-\gamma_R^2},\omega_0=(LC)^{-1/2}$$

$$\Delta=R^2-4L/C<0$$

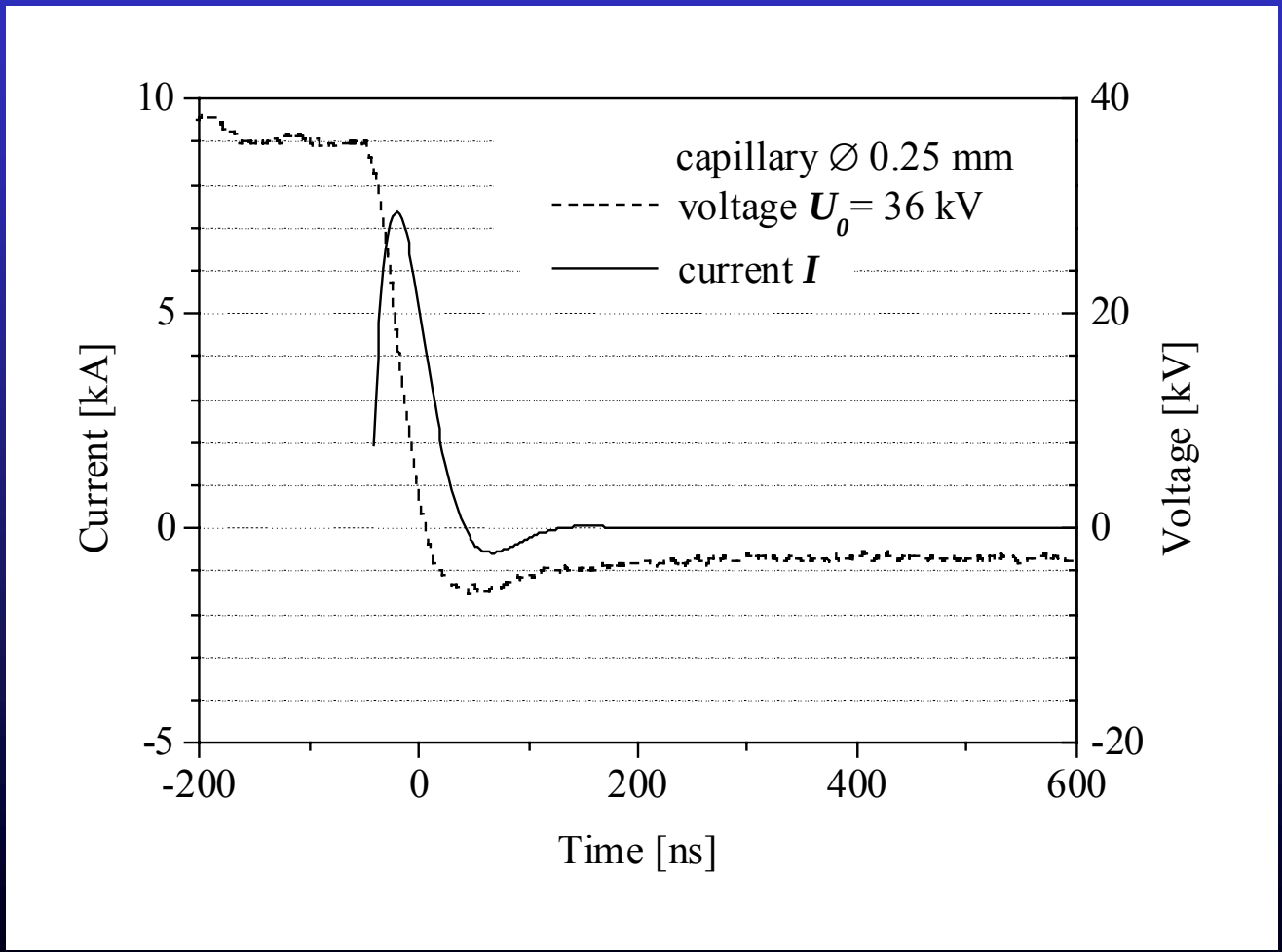
ω_0 is resonant frequency

$$I=-\frac{U_0}{L\omega_1}e^{-\gamma_R t}\sin\omega_1 t$$

Electrical and Optical Diagnostics...

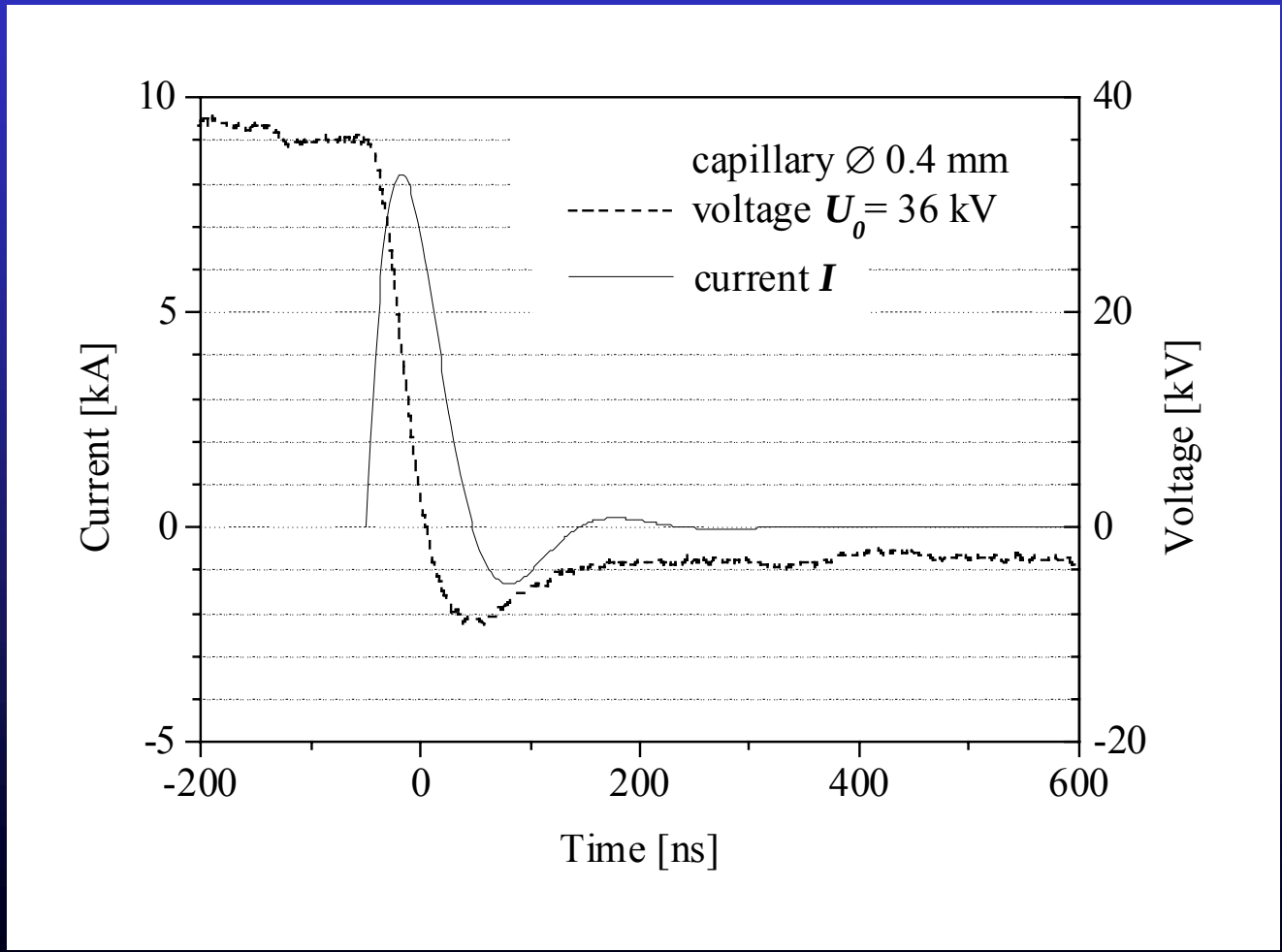
Voltage and current determination

Levenberg-Marquardt iteration by Origin 6.0 to calculate current



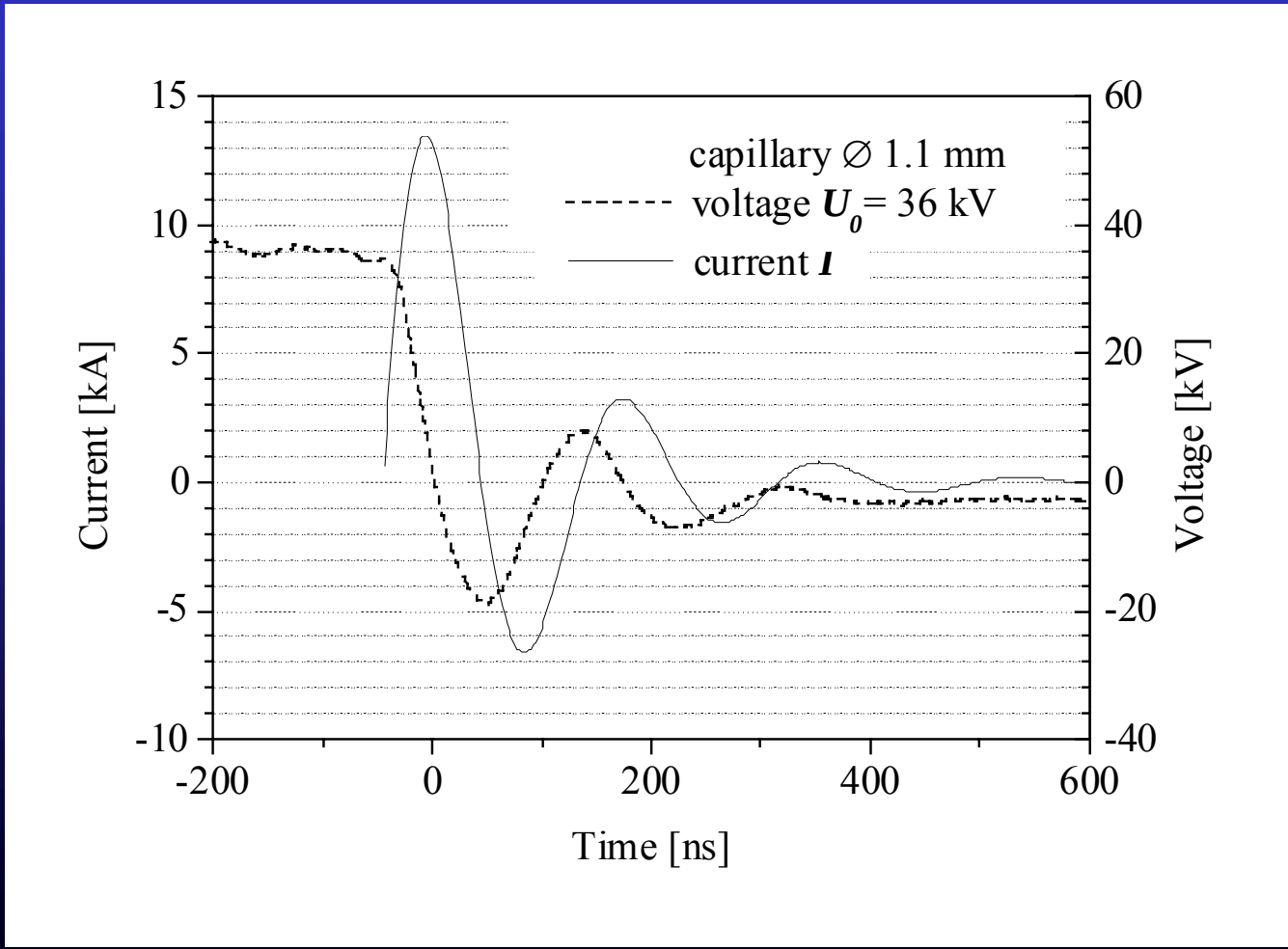
Electrical and Optical Diagnostics...

Voltage and current determination



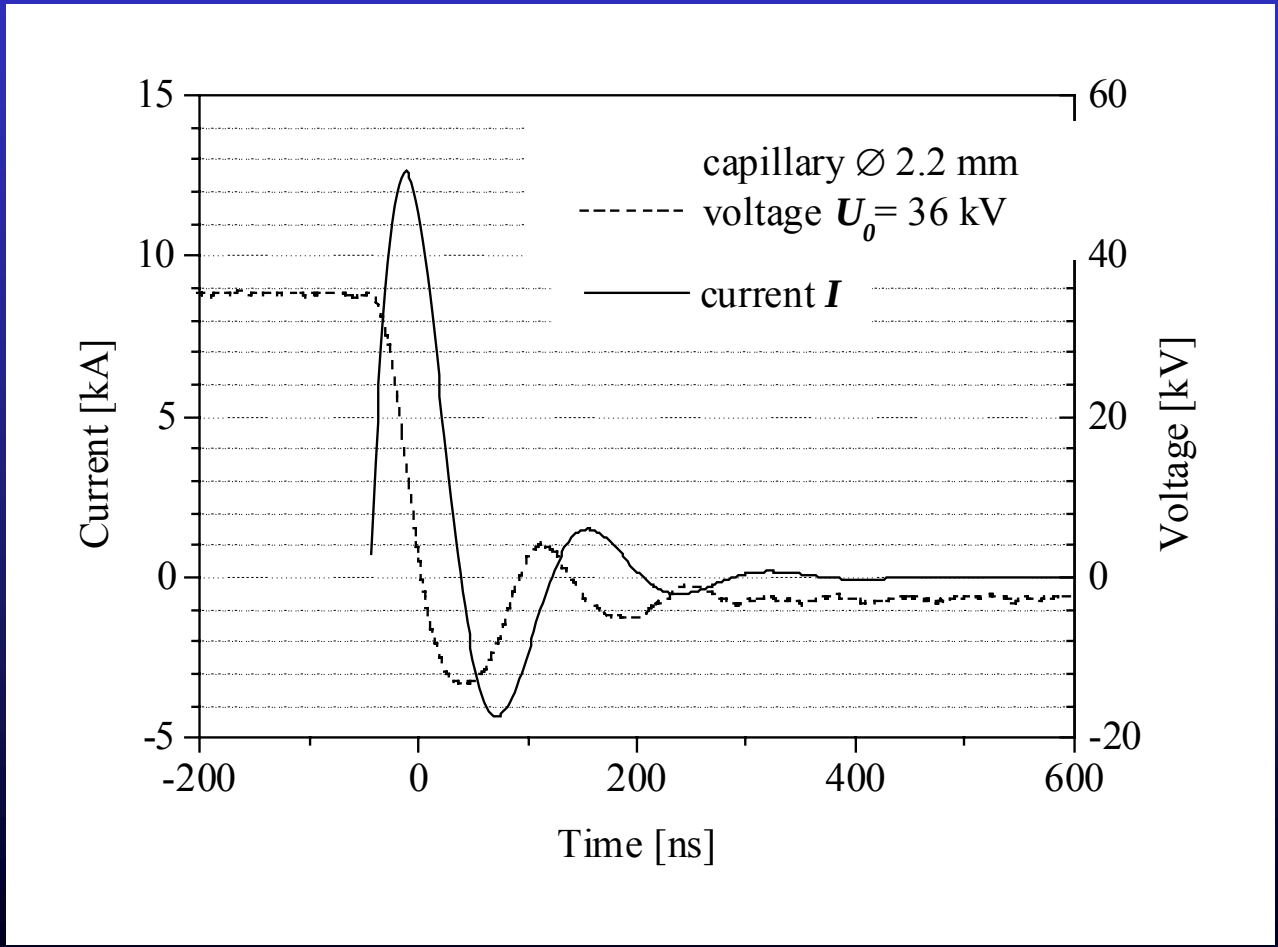
Electrical and Optical Diagnostics...

Voltage and current determination



Electrical and Optical Diagnostics...

Voltage and current determination



Electrical and Optical Diagnostics...

Voltage and current determination

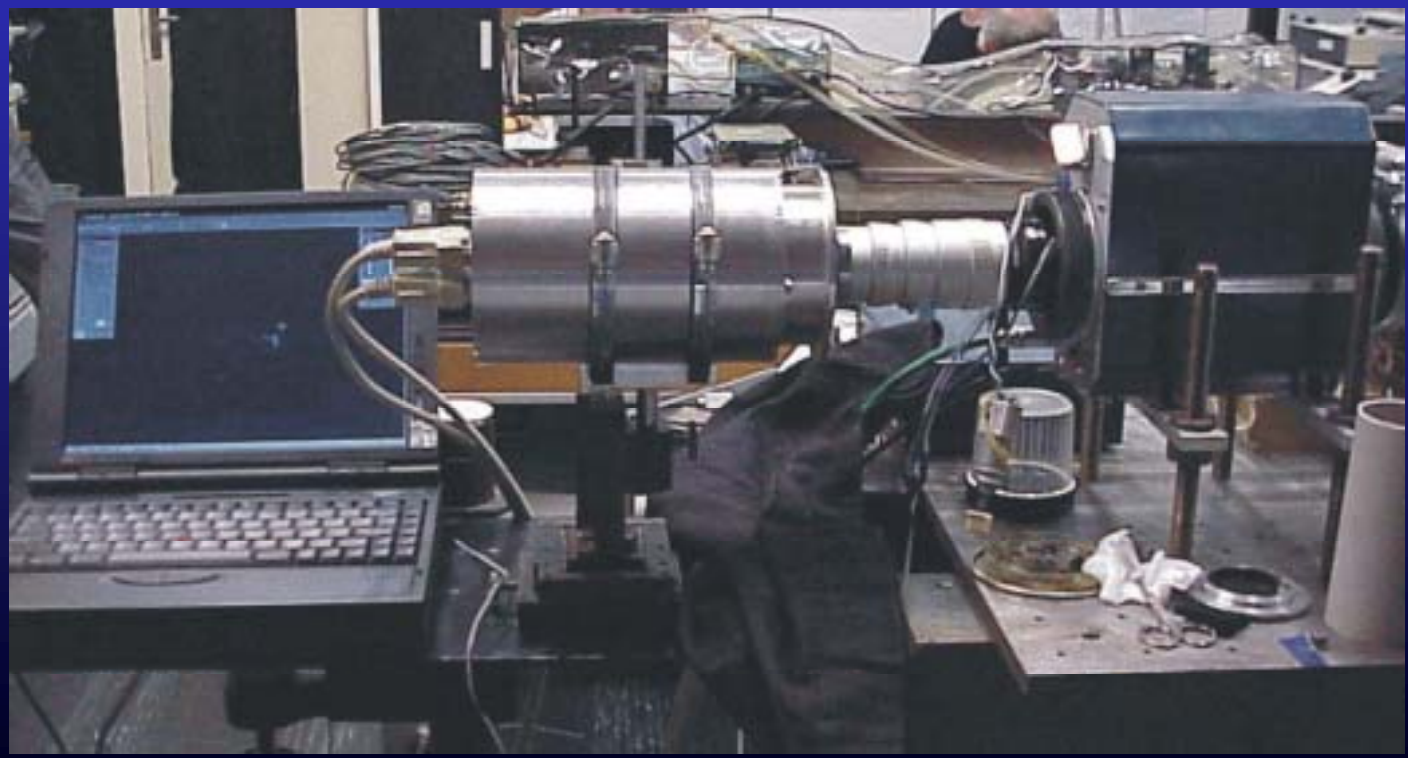
Capillary discharge circuit parameters U_0=36 kV

Capillary radius R_k	[mm]	0,125	0,2	0,55	1,1
Resistance R	[Ω]	3,0	2,4	0,9	1,2
Inductance L	[nH]	51	64	55	47
Capacity C	[nF]	15	15	15	15
$\Delta = R^2 - 4L/C$	[Ω^2]	-4,3	-11,0	-13,6	-11,3
Current ΔT (FWHM)	[ns]	54	60	60	56
Power density W	[GWcm^{-3}]	144	50	6,8	1,8
Resistivity ρ	[mΩ.cm]	0,6	1	5	15

Electrical and Optical Diagnostics...

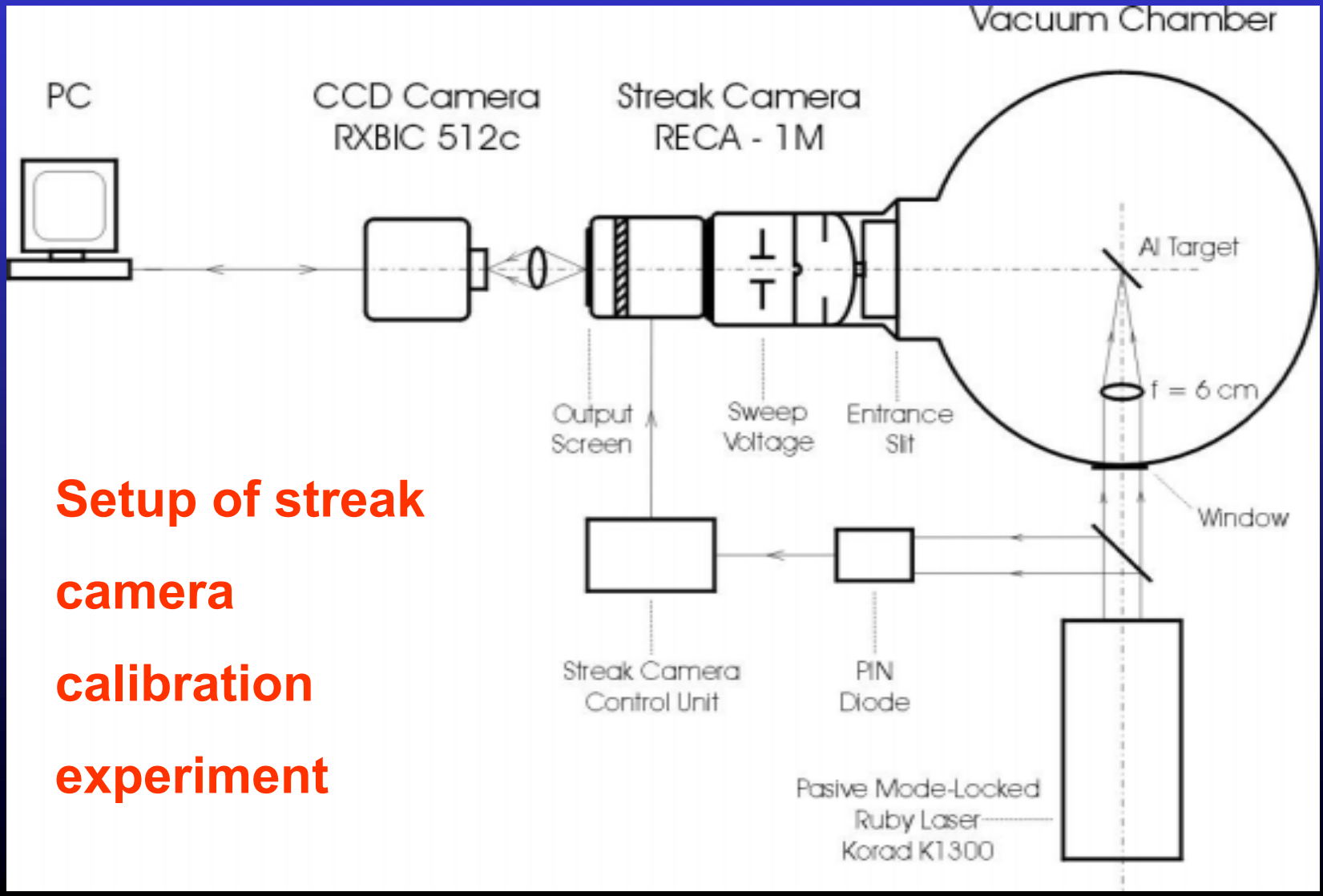
Streak Camera Calibration

RECA - 1M Streak Camera with RXBIC 512c BICCD Camera



Electrical and Optical Diagnostics...

Streak Camera Calibration

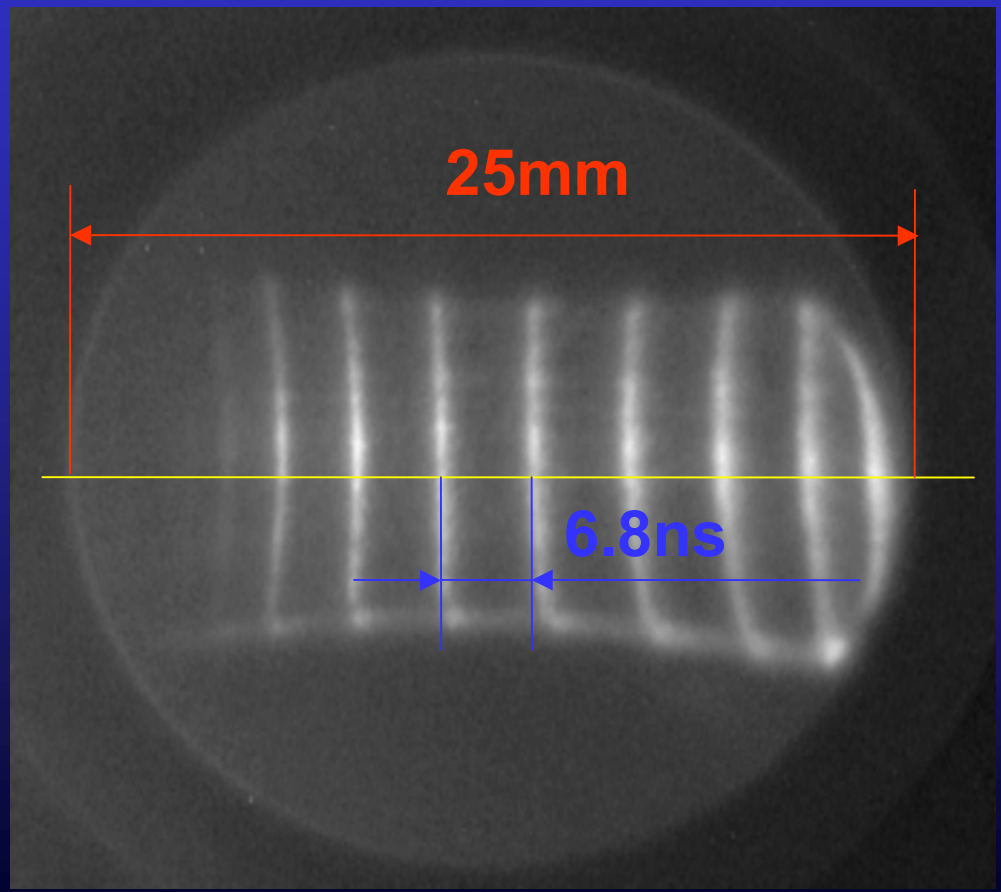


Setup of streak camera calibration experiment

Electrical and Optical Diagnostics...

Streak Camera Calibration

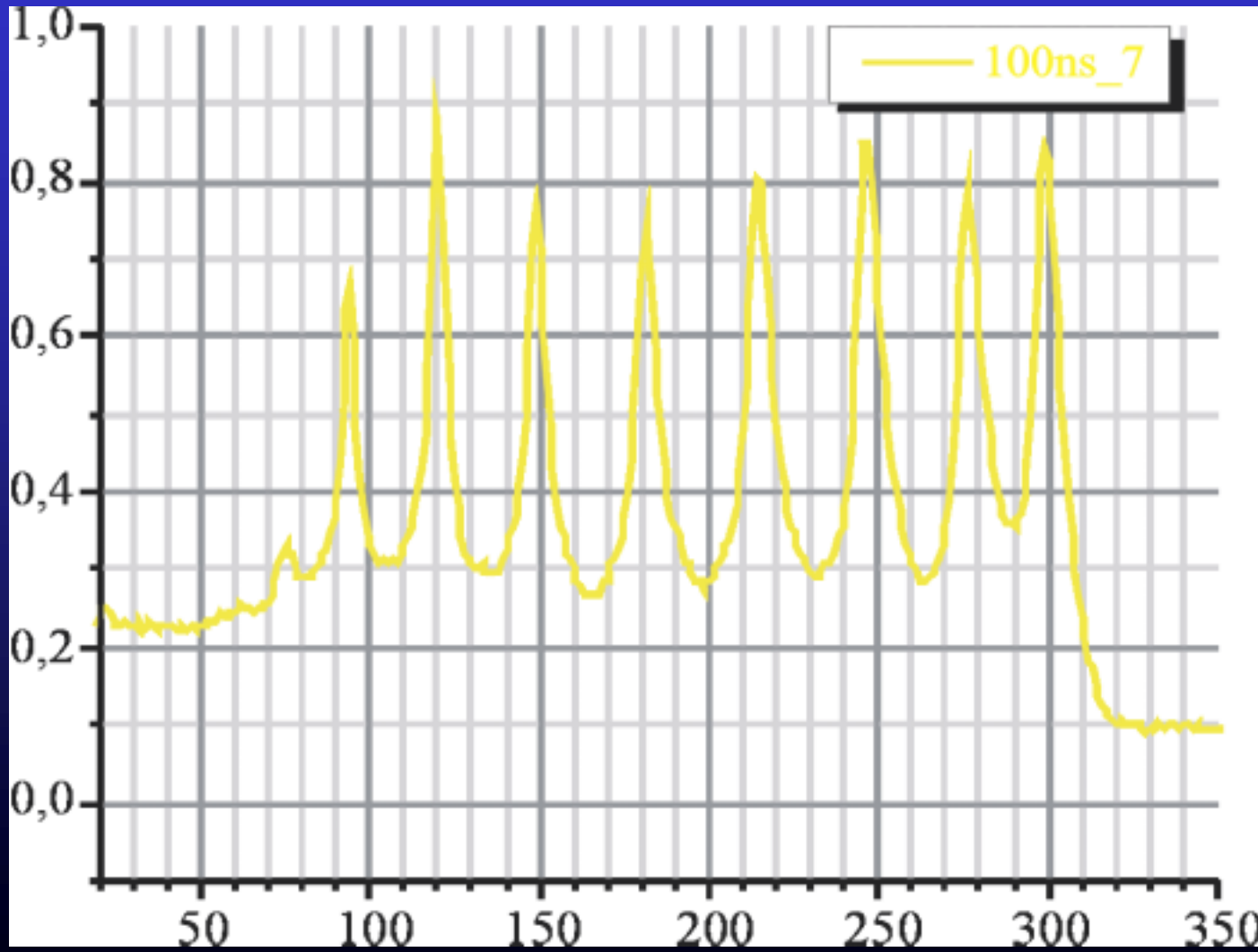
CCD grab of streak camera phosphor screen with ruby laser modelocked pulse train for "100 ns" streak time



Electrical and Optical Diagnostics...

Streak Camera Calibration

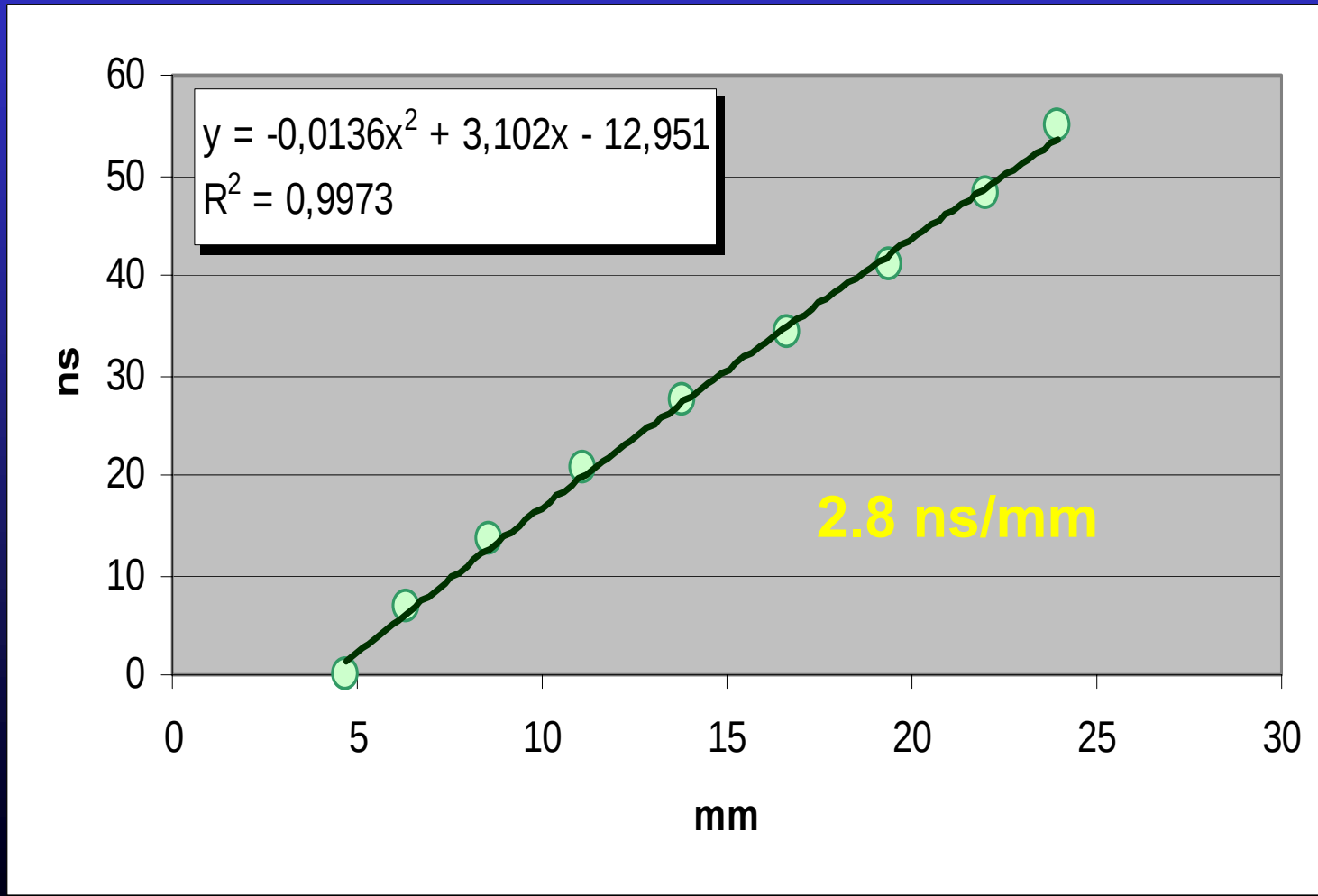
Graph of luminosity versus CCD pixels taken from previous CCD grab



Electrical and Optical Diagnostics...

Streak Camera Calibration

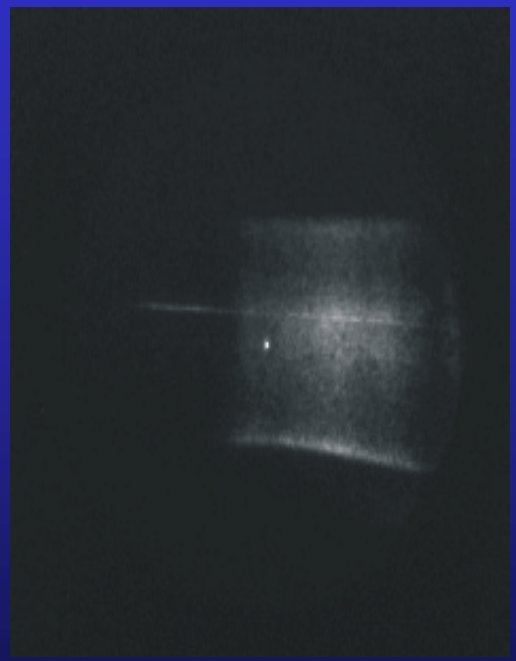
RECA-1M streak camera interpolation curve for “100”ns streak

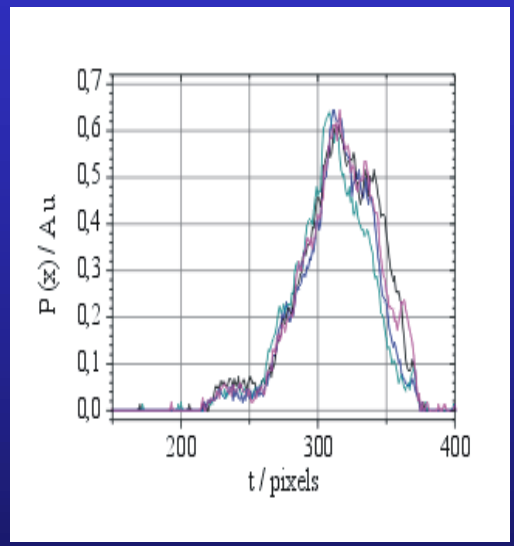


Electrical and Optical Diagnostics...

Curve of XUV radiation

a)





b)

Timedependance of polyacetal capillary discharge XUV radiation, Φ = 1,1mm; voltage U_0 = 40 kV meassured by streak camera RECA – 1M a) CCD grab of streak camera screen b) dependance of screen luminosity on location in horizontal cut for 4 pulses

Electrical and Optical Diagnostics...

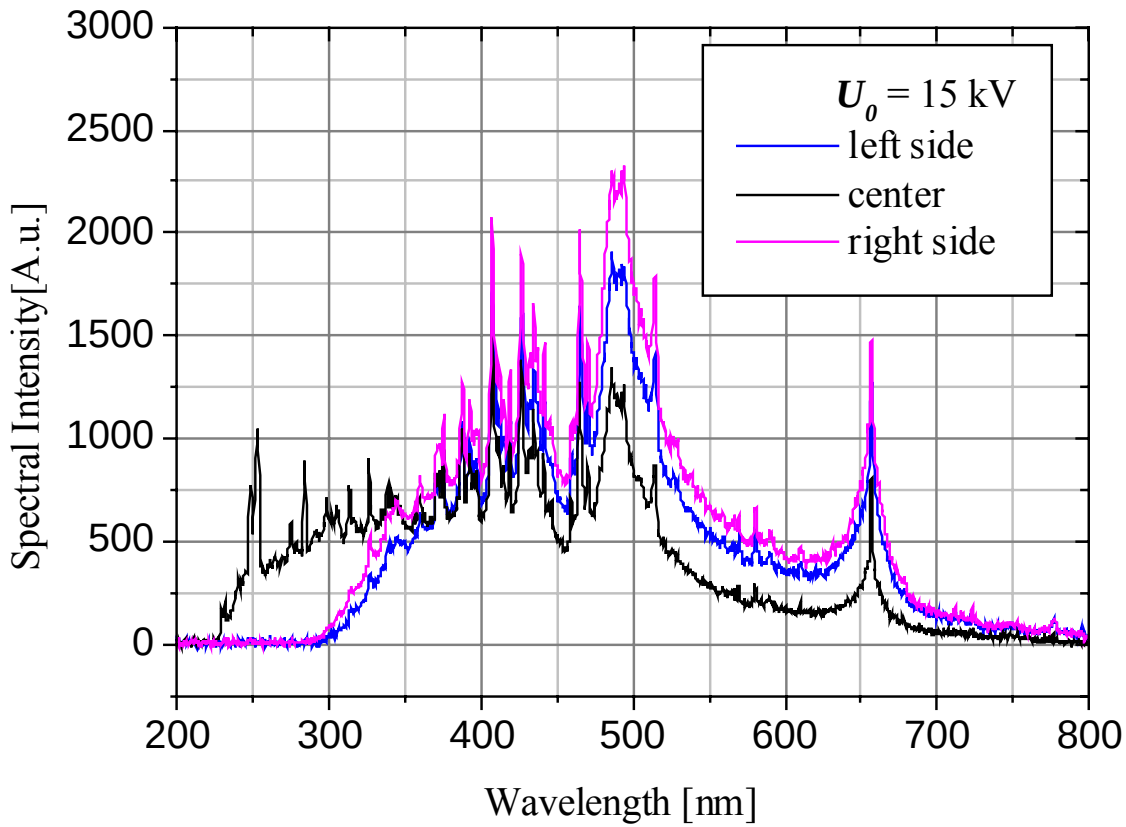
UV spectrum measurement

Time integrated UV-VIS spectra measurement with PC2000

Ocean Optics PC 2000 fibre optics spectrometer uses CCD 2048 pixels array integrated with holographic grating (1200 line/mm) and 25 μm slit into common block. This block is mounted on PC card with ISA bus. CCD detector is covered by UV antireflection coating, grating is blazed to 250 nm. Spectral range is 190 – 800 nm with 1.8 nm resolution. Polyacetal capillary discharge radiation is guided to spectrometer by UV enhanced quartz fibre with core diameter 200 μm.

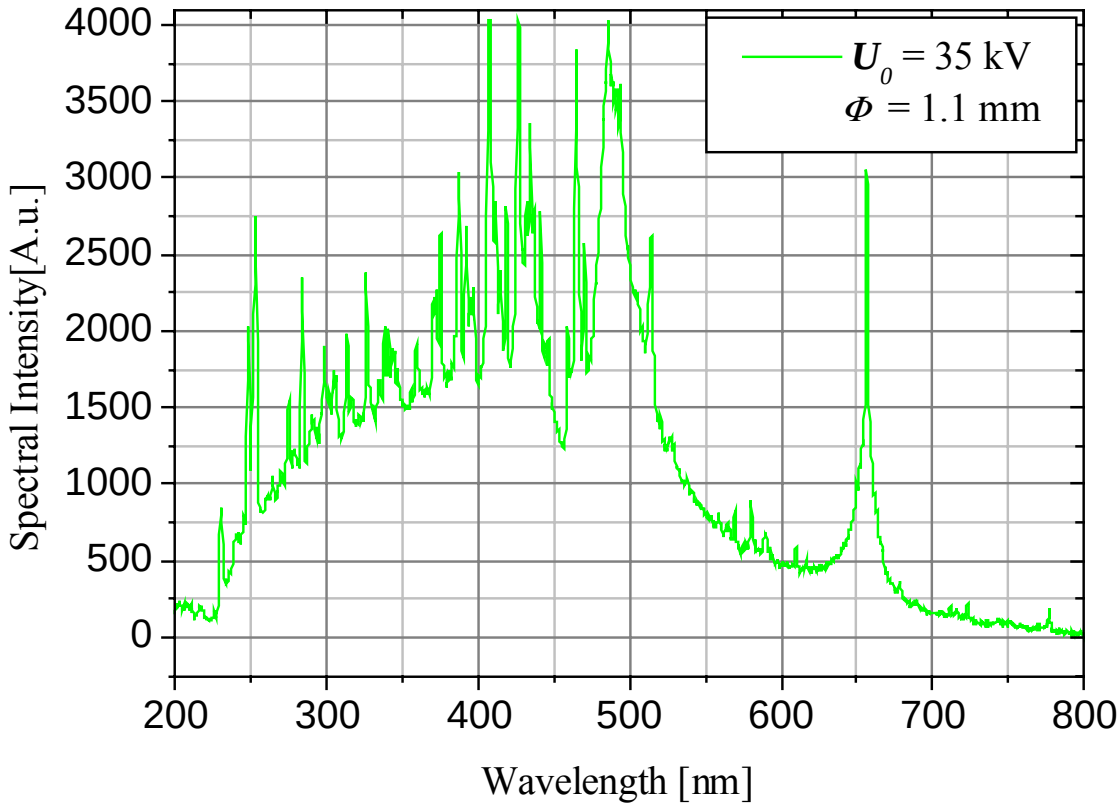
Electrical and Optical Diagnostics...

UV spectrum measurement



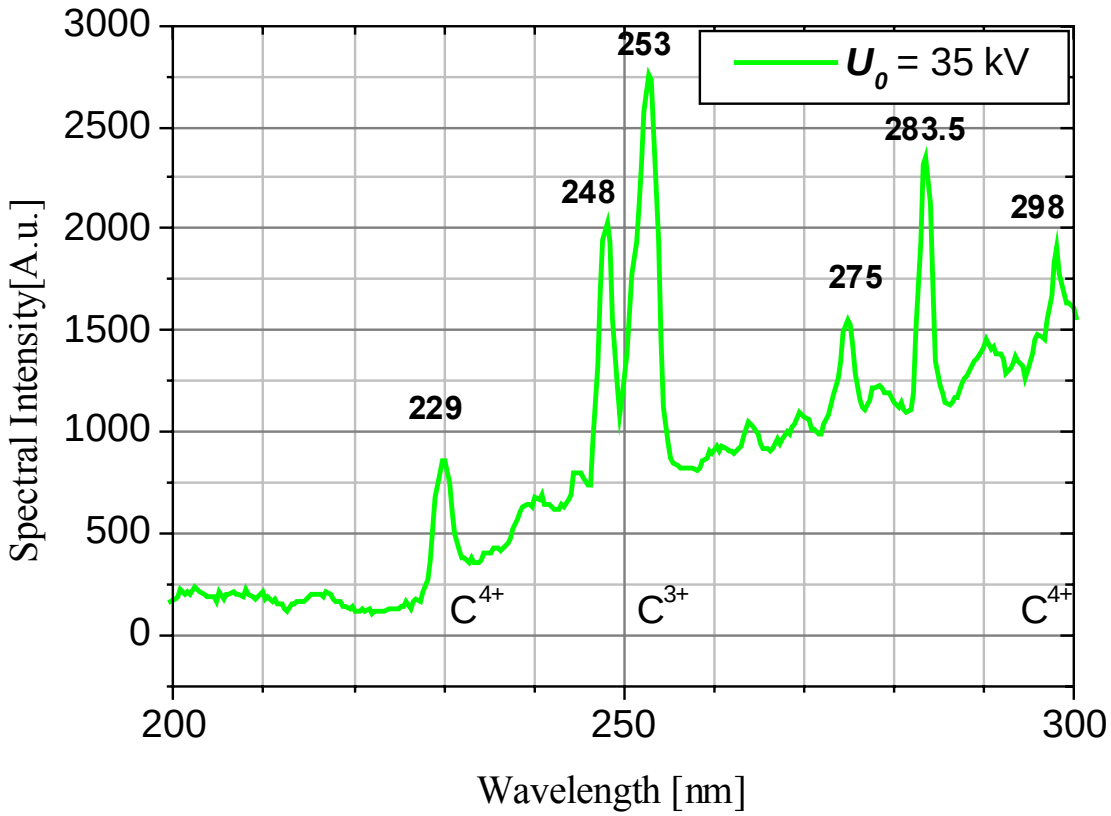
Electrical and Optical Diagnostics...

UV spectrum measurement



Electrical and Optical Diagnostics...

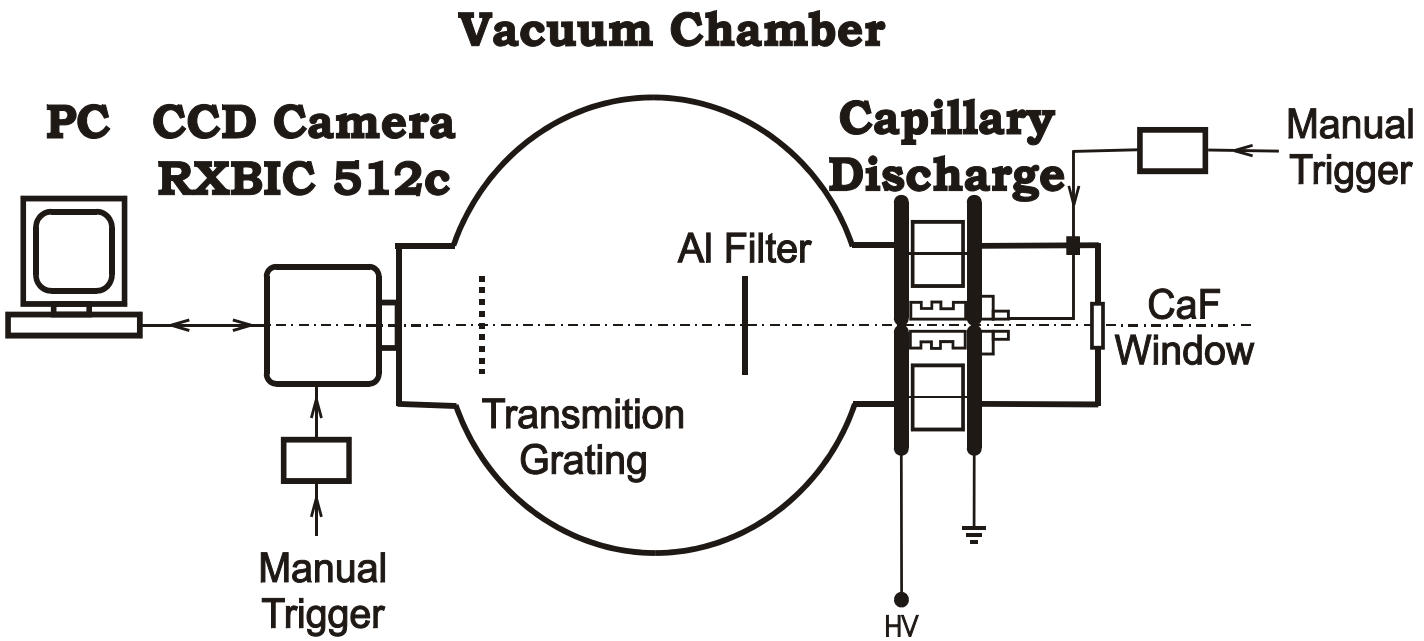
UV spectrum measurement



Electrical and Optical Diagnostics...

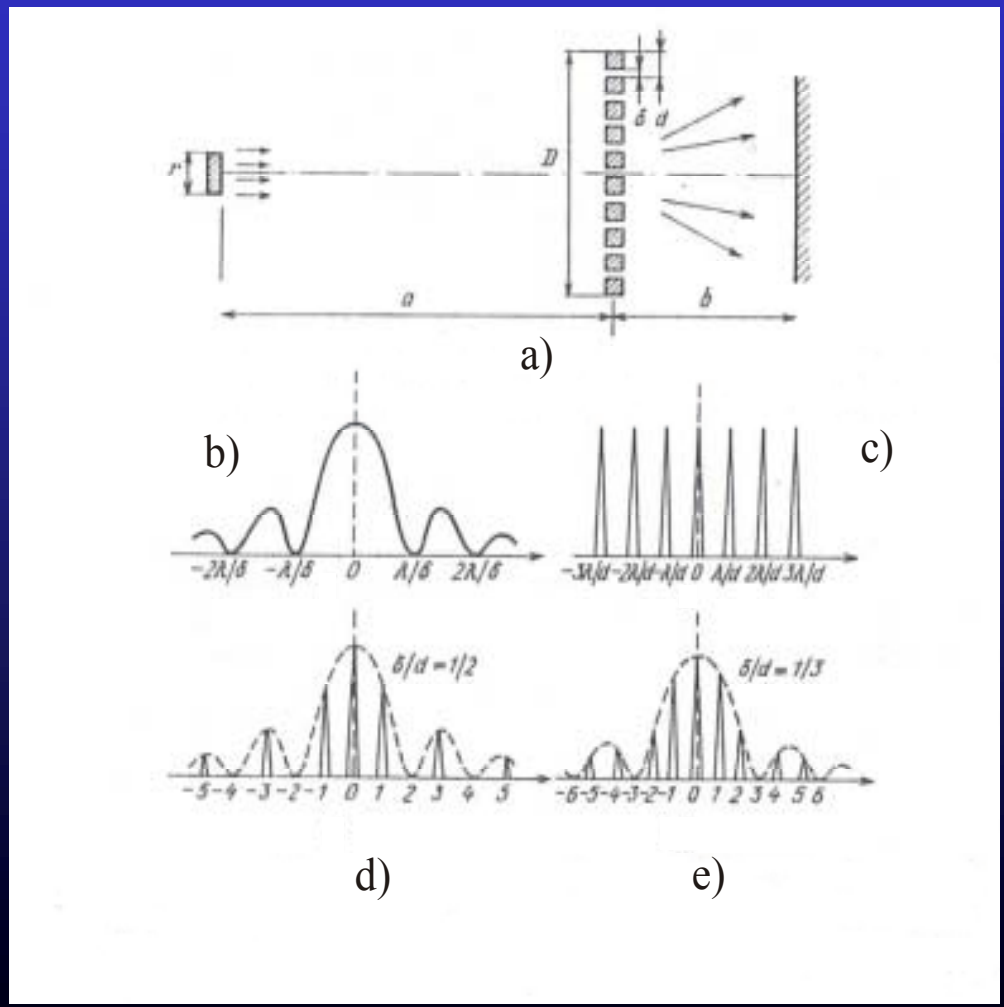
X spectrum measurement

Time-integrated X spectrum measurement setup



Electrical and Optical Diagnostics...

X spectrum measurement



Golden freestanding

TGS

period $d = 1.4\ \mu m$

gap $\delta = 0.7\ \mu m$

ratio $\delta/d = 1/2$

width $D = 70\ \mu m$

source $r = 1100\ \mu m$

distance $a = 400$ mm

$b = 330$ mm

Electrical and Optical Diagnostics...

X spectrum measurement

Transmition grating spectrometer

PARAMETR	DESCRIPTION	UNIT	GEOM4
Capillary diameter	Φ	[mm]	1,10
Wavelength	λ	[nm]	18,0
Grating period	d	[μm]	1,4
Gap width	δ	[μm]	0,7
Grating width	D	[μm]	70,0
Source width	r	[μm]	1100,0
Source-grating distance	a	[mm]	400,0
Source-screen distance	b	[mm]	330,0
Screen width	s	[mm]	6,2
Screen width	$spix$	[pixel]	512,0
Dispersion	d/b	[nm/mm]	4,24
Dispersion	$d/b*s/spix$	[nm/pixel]	0,05
Diffraction limit	$M_D=D/d$	[1]	50,0
Geom. diffraction limit	$M_G= \lambda/\Delta\lambda_G$	[1]	4,1
Spectrum width/screen		[nm/screen]	26,3
Spectral resolution	$\Delta\lambda=\Delta\lambda_D+\Delta\lambda_G$	[nm]	4,8
By diffraction	$\Delta\lambda_D = \lambda/M_D$	[nm]	0,4
By geometry	$\Delta\lambda_G=d(D/b+(r+D)/a)$	[nm]	4,4
0^{TH} order width	$\delta\lambda_0=(d/b)D$	[nm]	0,3

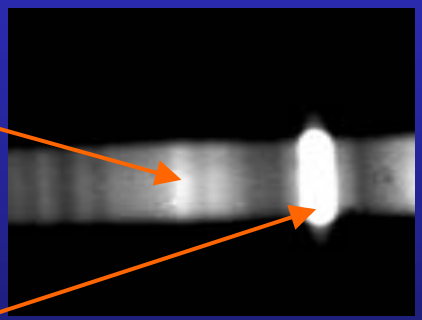
Electrical and Optical Diagnostics...

X spectrum measurement

BICCD camera snaps

1ST order

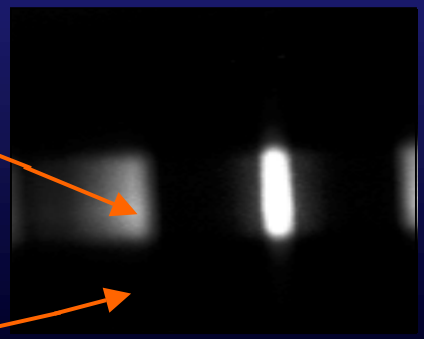
λ ~ 18 nm



0TH order

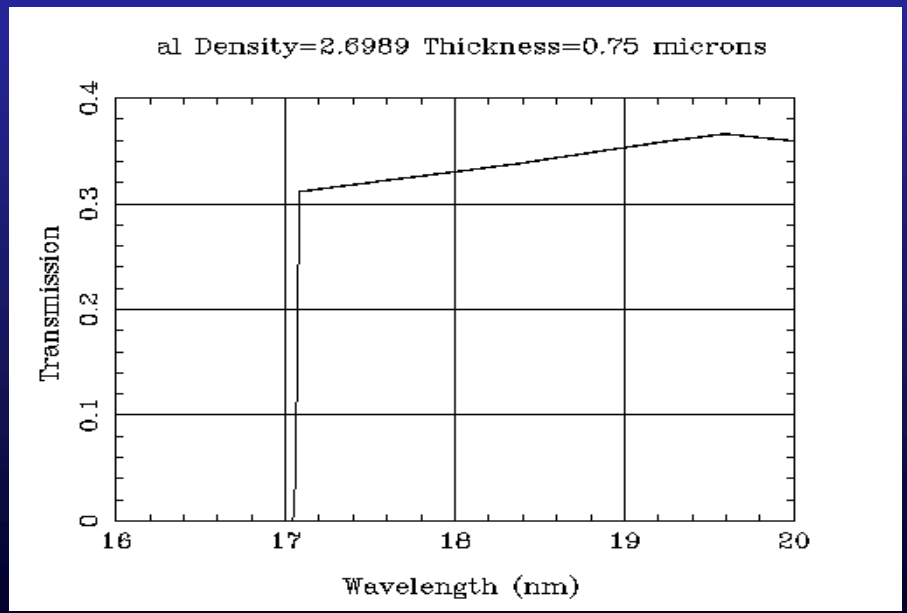
Al filter edge

17.1 nm



Background

0.75 μm Al foil filter transmittance



http://www-cxro.lbl.gov/optical_constants/filter2.html

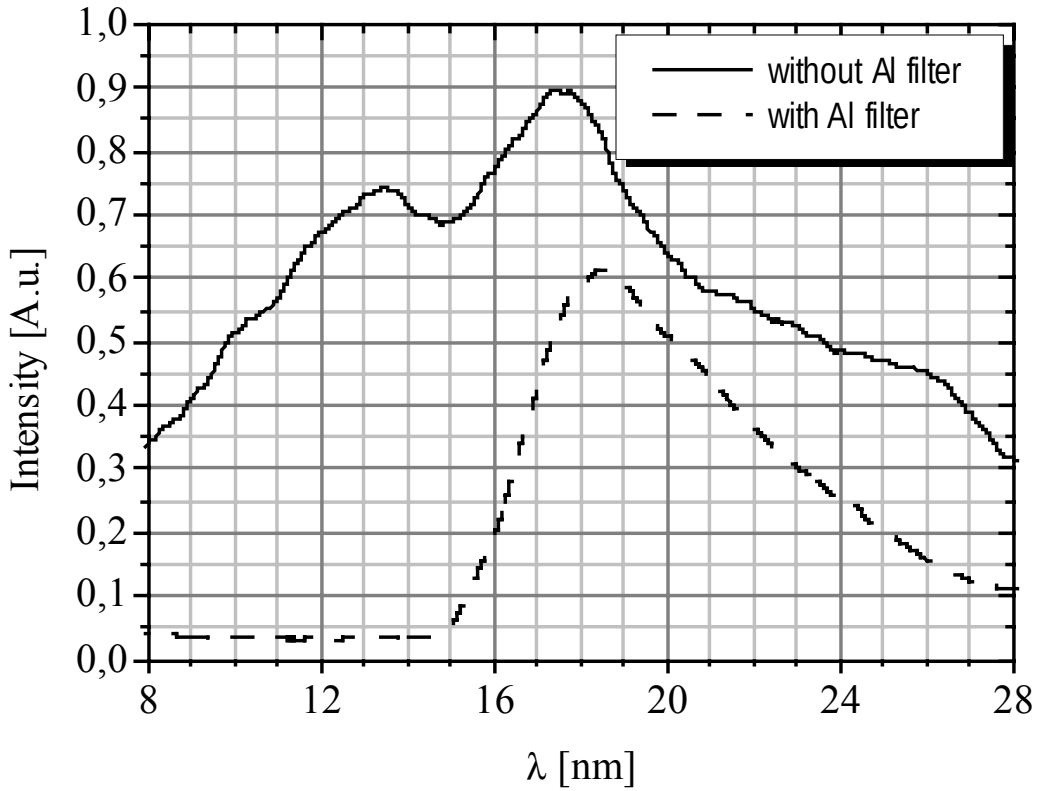
Electrical and Optical Diagnostics...

X spectrum measurement

Polyacetal capillary discharge X-ray spectra

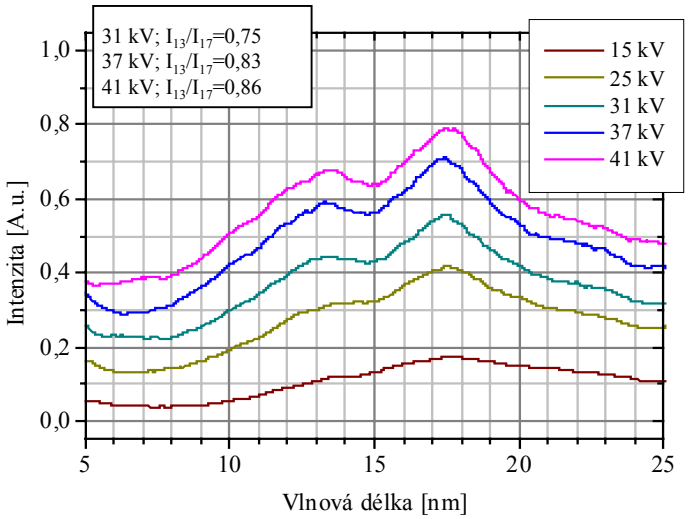
U_0 = 41 kV

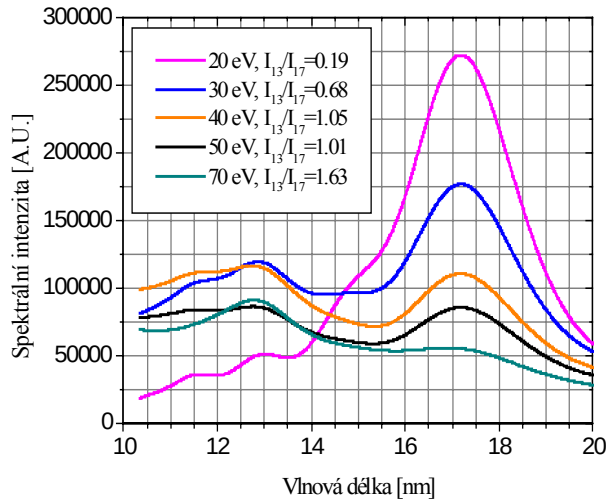
Φ = 1.1 mm



Electrical and Optical Diagnostics...

Electron temperature lower estimation





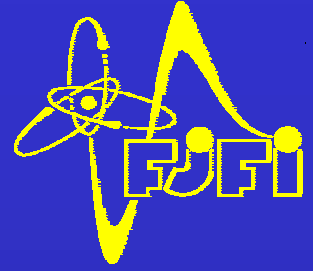
Meassured spectral intensity

Simulated spectral intensity

(Limpouch J. et al.:)

From peak ratio I_{13}/I_{17} T_e > 30 eV

Electrical and Optical Diagnostics of Polyacetal Capillary Discharge



Conclusions:

1. Experimental system to study capillary discharge was built
2. Time dependencies of voltage and current in discharge circuit were stated
3. Sweep rates of streak camera was calibrated
4. Time integrated spectra in UV and X range were measured
5. Lower estimation of electron temperature was done

Electrical and Optical Diagnostics of Polyacetal Capillary Discharge

Literature:

Vrbová M., Jančárek A., Pína L.,Vrba P., Bobrova N.A., Sasorov P.V., Kálal M. and Nádvorníková L.: *A Study of Electrical Discharge in Polyacetal Capillary Discharge*, Journal de Physique IV, **11** (2001) 575

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Limpouch J. et al.: **http://www-troja.fjfi.cvut.cz/k412/cz**