Russian Federal Nuclear Center –
All-Russian Research Institute of Experimental Physics
RFNC-VNIIEF

EXPERIMENTAL STUDY OF EM RADIATION FROM THE FASTER-THAN-LIGHT VACUUM MACROSCOPIC SOURCE

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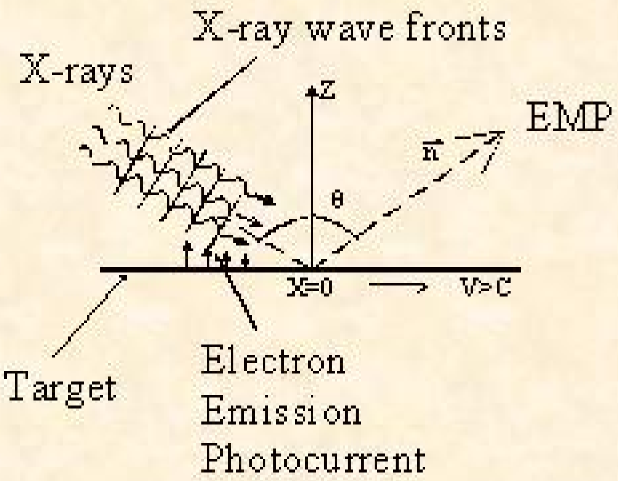
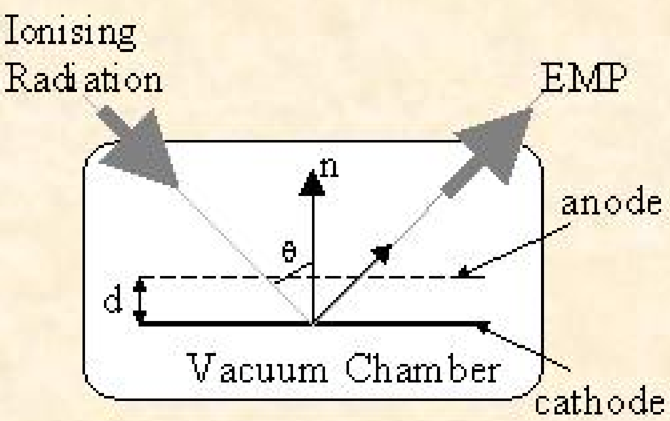
Schemes of EMP generation

Scheme of the EMP generation in case an infinite conductive target (*N.J. Carron and C.L.Longmire, 1976*)



Scheme of EMP device (*Yu.N.Lasarev, P.V.Petrov, 1994*)

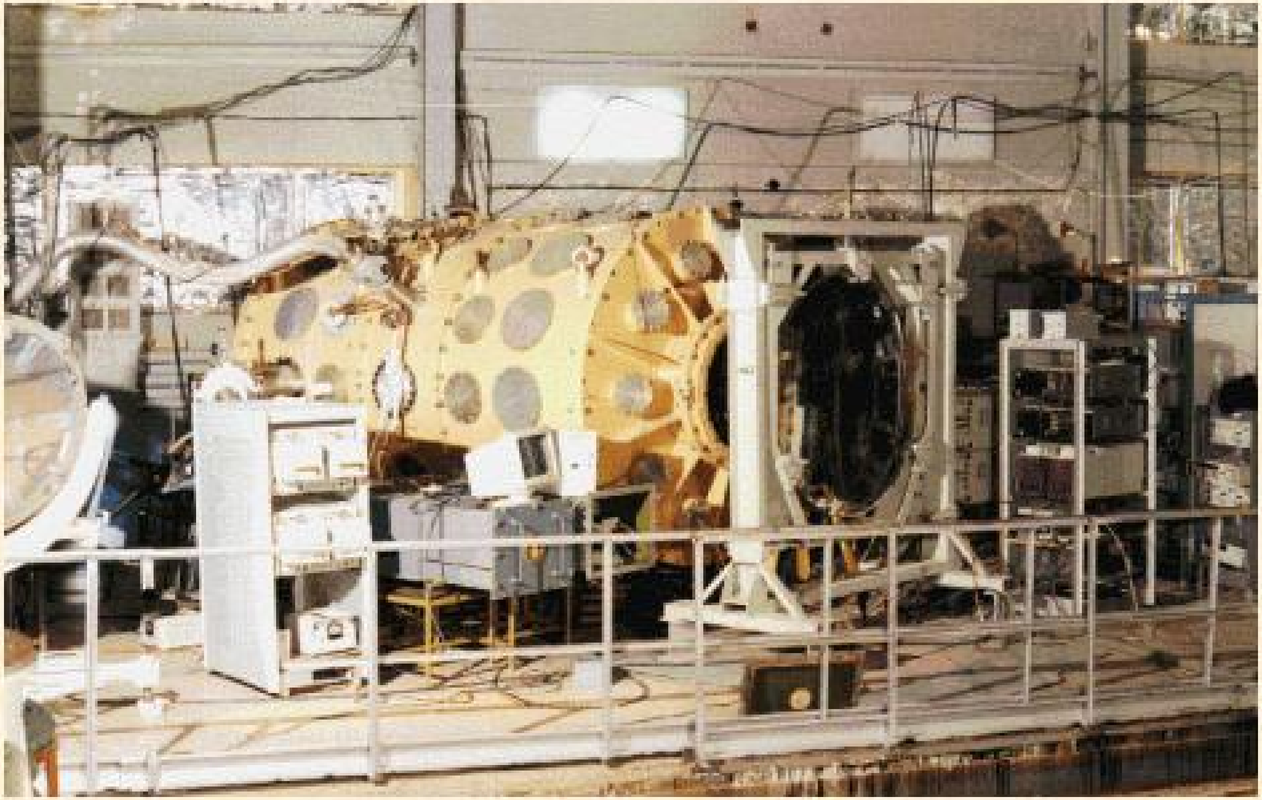


B~ dP/dt $(L \gg c\tau_x)$ *or* d^2P/dt^2 $(L \ll c\tau_x)$; $P \sim \varepsilon_e$; $B \sim \varepsilon_e$; $\tau_R \sim (\omega_{Le})^{-1} \sim n_e^{-1/2}$; $n_e \sim J_X$.

B-field; P-dipole moment per unit area; ε_e , n_e *-electron energy and density;*

τ_x , τ_R*-X-ray and EMP pulse duration;* J_X*-X-ray intensity; L-target dimensions*

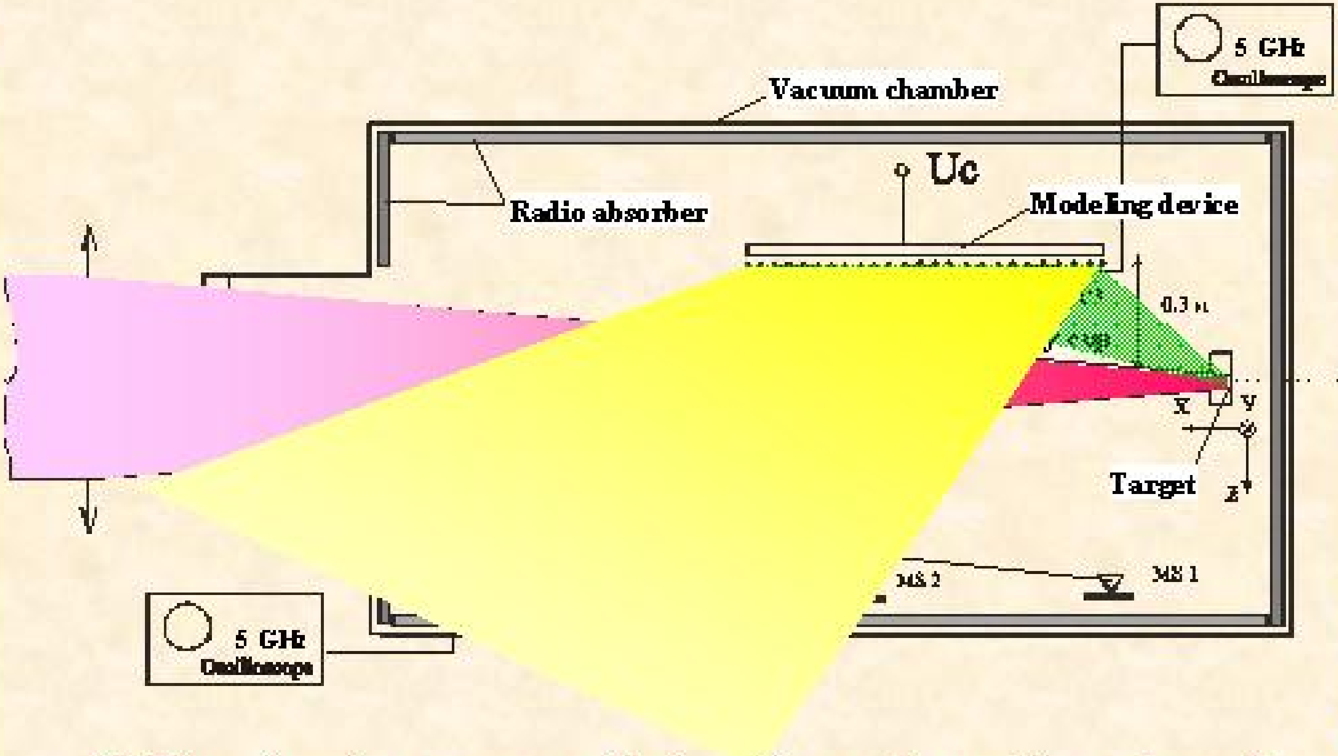
Experimental setup for EMP research on "Iskra-5" laser facility



Research equipment:

	"echo-less" vacuum chamber	Ø 1950 × 2994 mm
	vacuum system	$P \sim 1\times10^{-4}$ Torr
	high voltage power supply system	$U_{max}=100$ kV
	optical scheme of input laser radiation	$E_{1\omega}\cong 900$ J, $E_{2\omega}\cong 300$ J,
		$\lambda=1.315$ μm, $\tau_{0.5}\approx 0.3$ ns
		$Q\sim10^{14\div15}$ W/cm^2

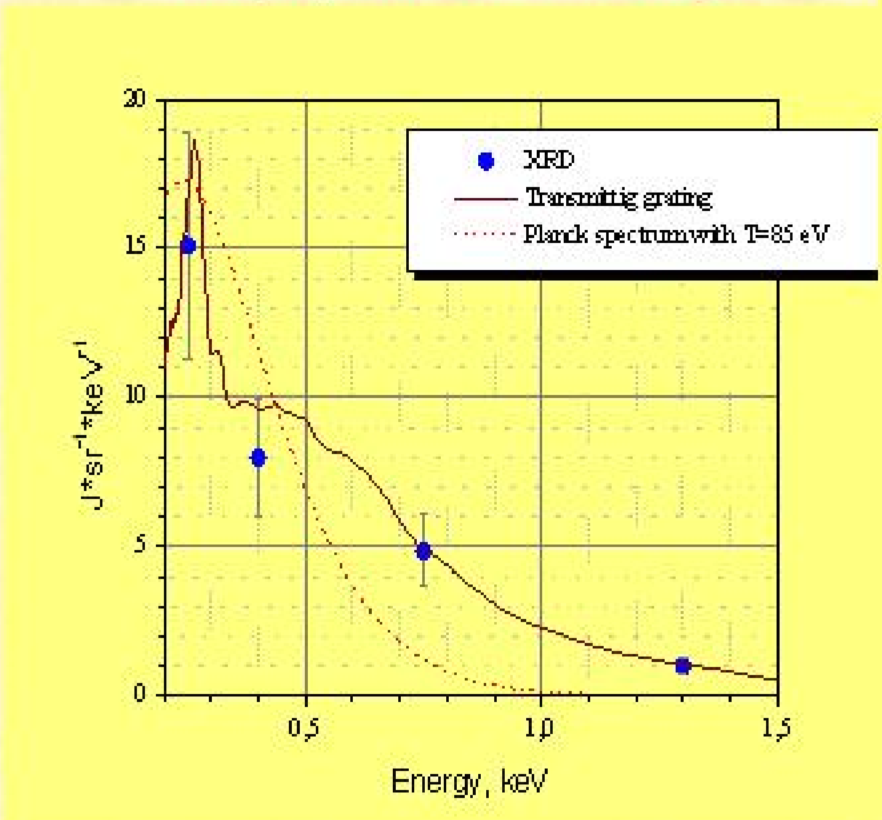
Experimental set-up



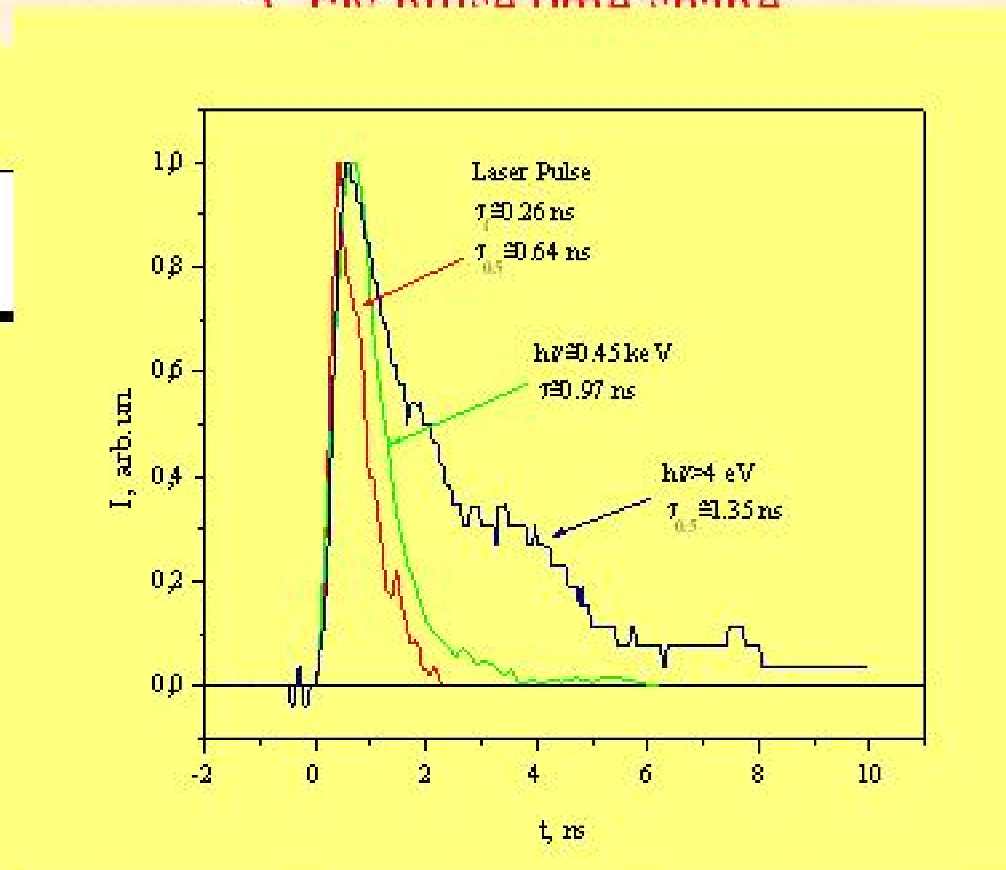
- The chamber was supplied with a diagnostic system for measurements of current parameters, and parameters of incident X-ray and investigated EMP
- rise time of accelerated electron current sensors was 75 ps
- rise time of field sensor was ≤ 40 ps.

X-rays parameters

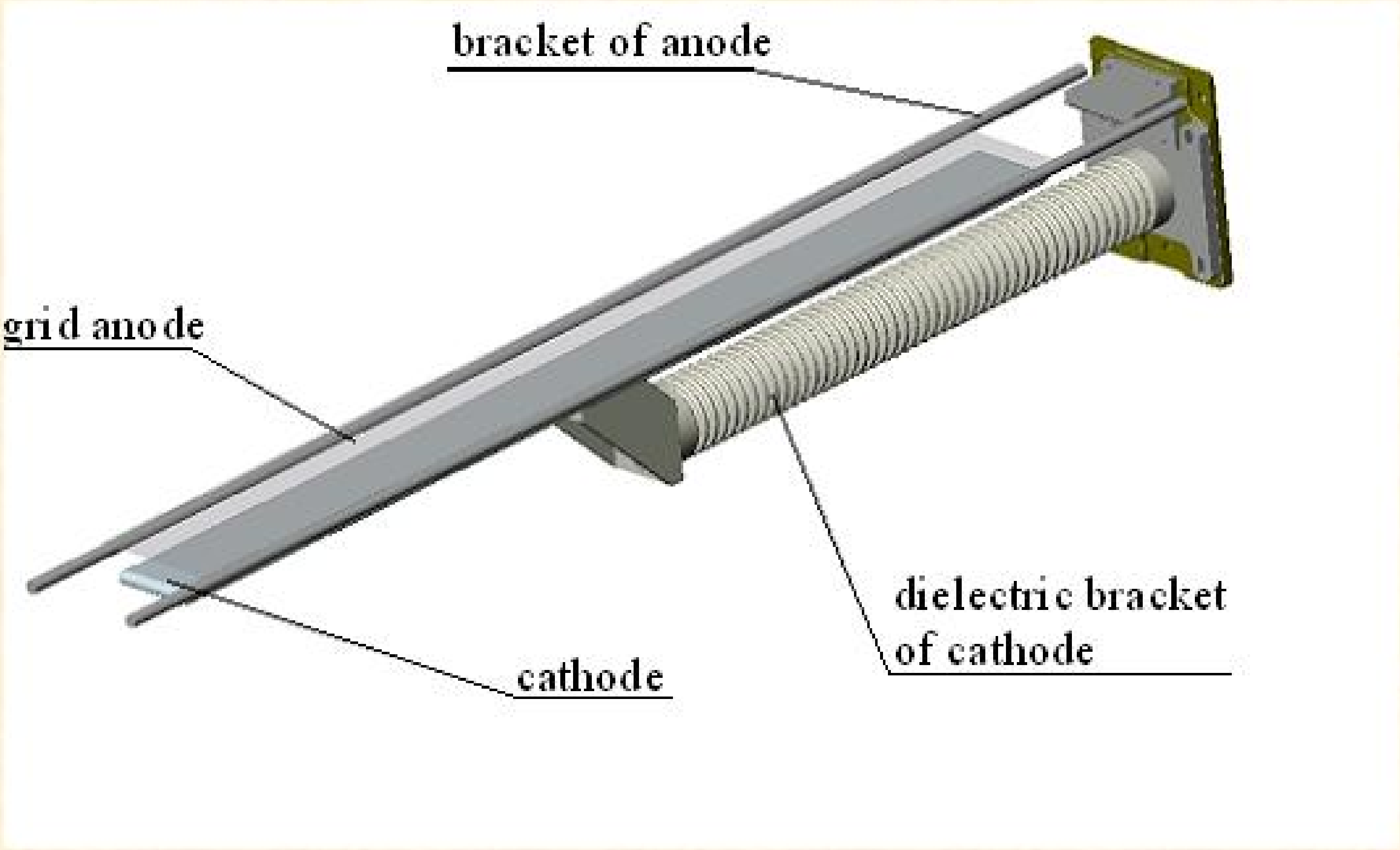
X-ray spectrum of Au target



X-ray pulse time shape

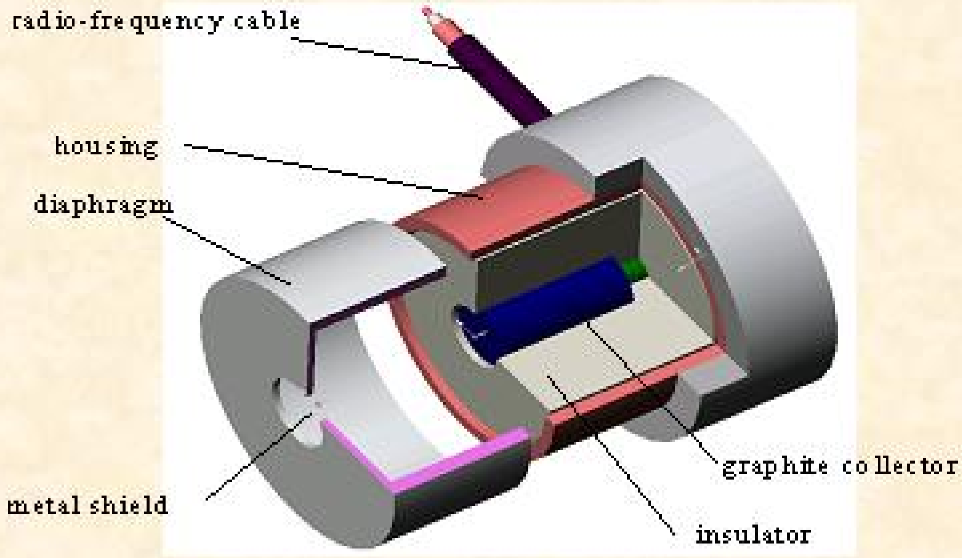


Radiating unit design (plane diode)

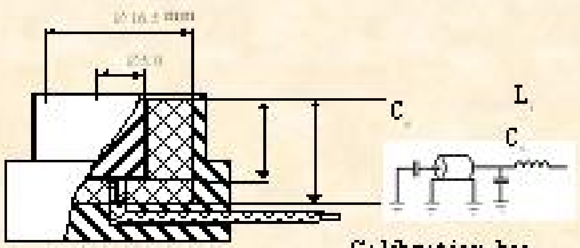


Faraday cup

Design of accelerated electron current sensor



Sensor geometry
and equivalent electric circuit

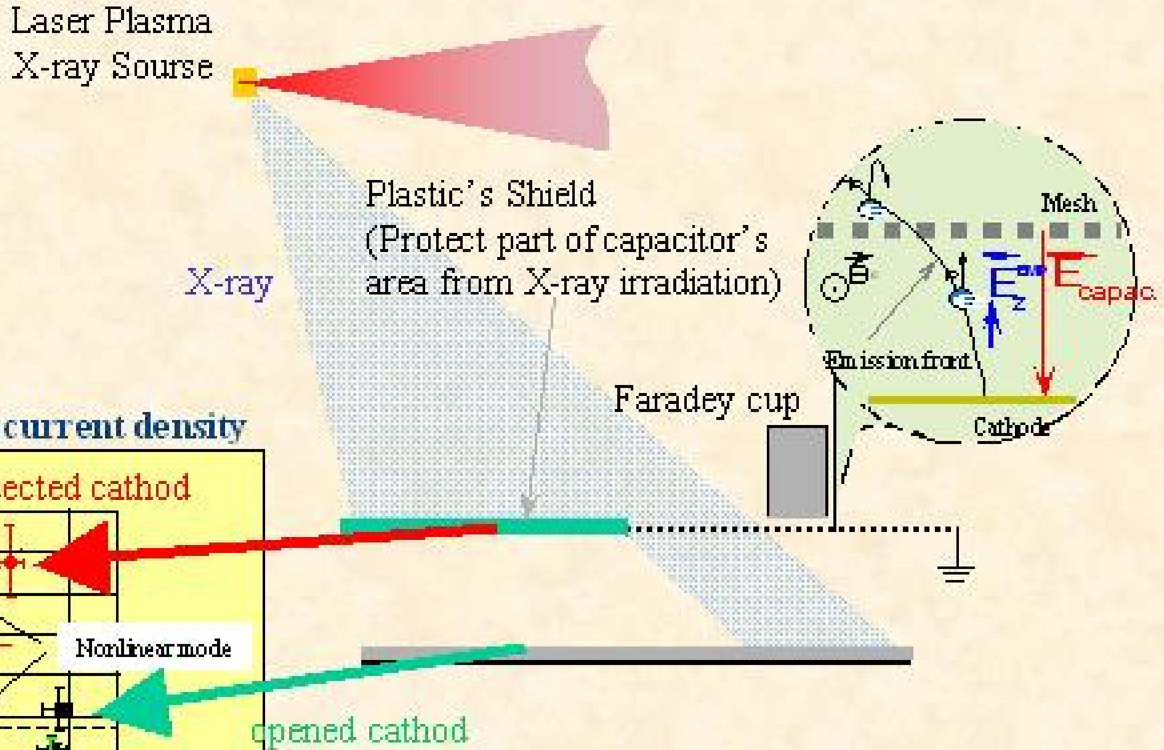


Calibration by
scatterometry method
Measurement setup: δ-generator - $U_{max} \approx 11$ V
$\tau \approx 43$ ps
sampling oscilloscope bandwidth >12 GHz

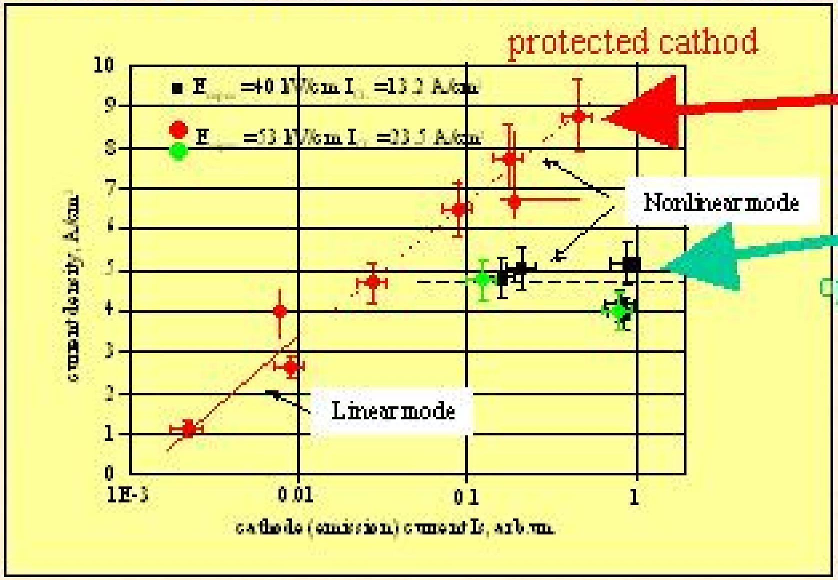
Calculated step response of Faradey Cup

Rise time of electron current sensor $\tau = 73$ ps

Anode electron current vs emission current

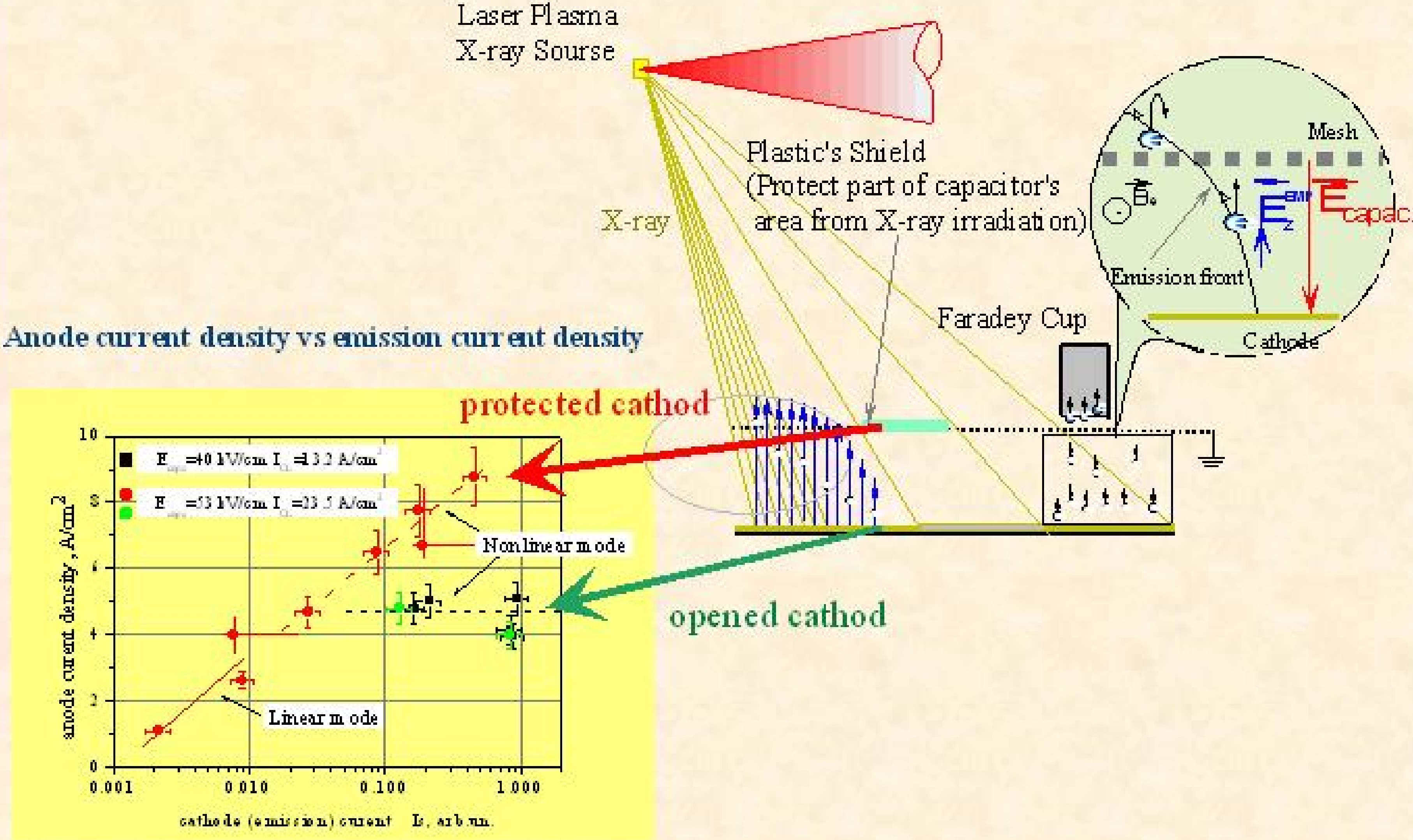


Anode current density vs emission current density

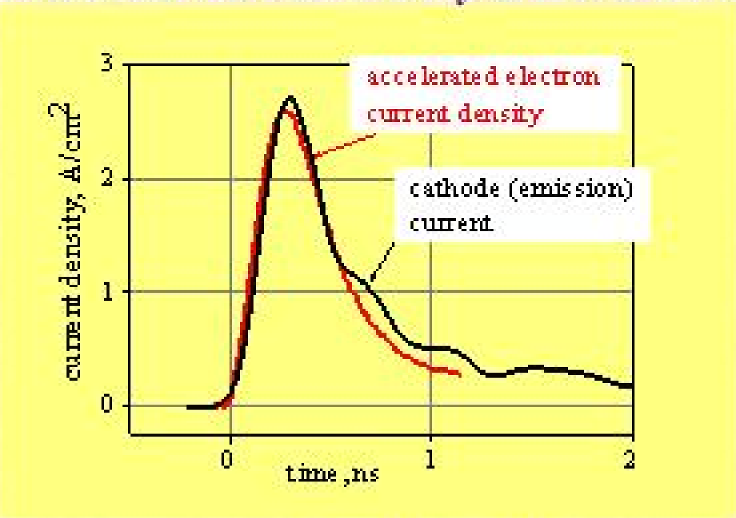


Anode electron current vs emission current (cont.)

Anode current density vs emission current density

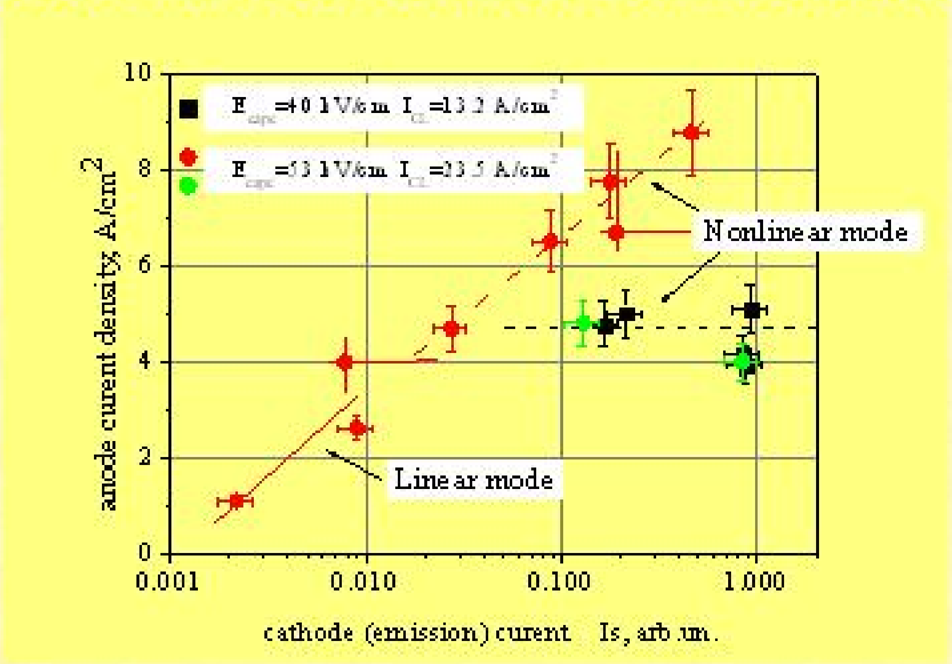


The time dependences of the electron current density I_r and emission current density in linear mode

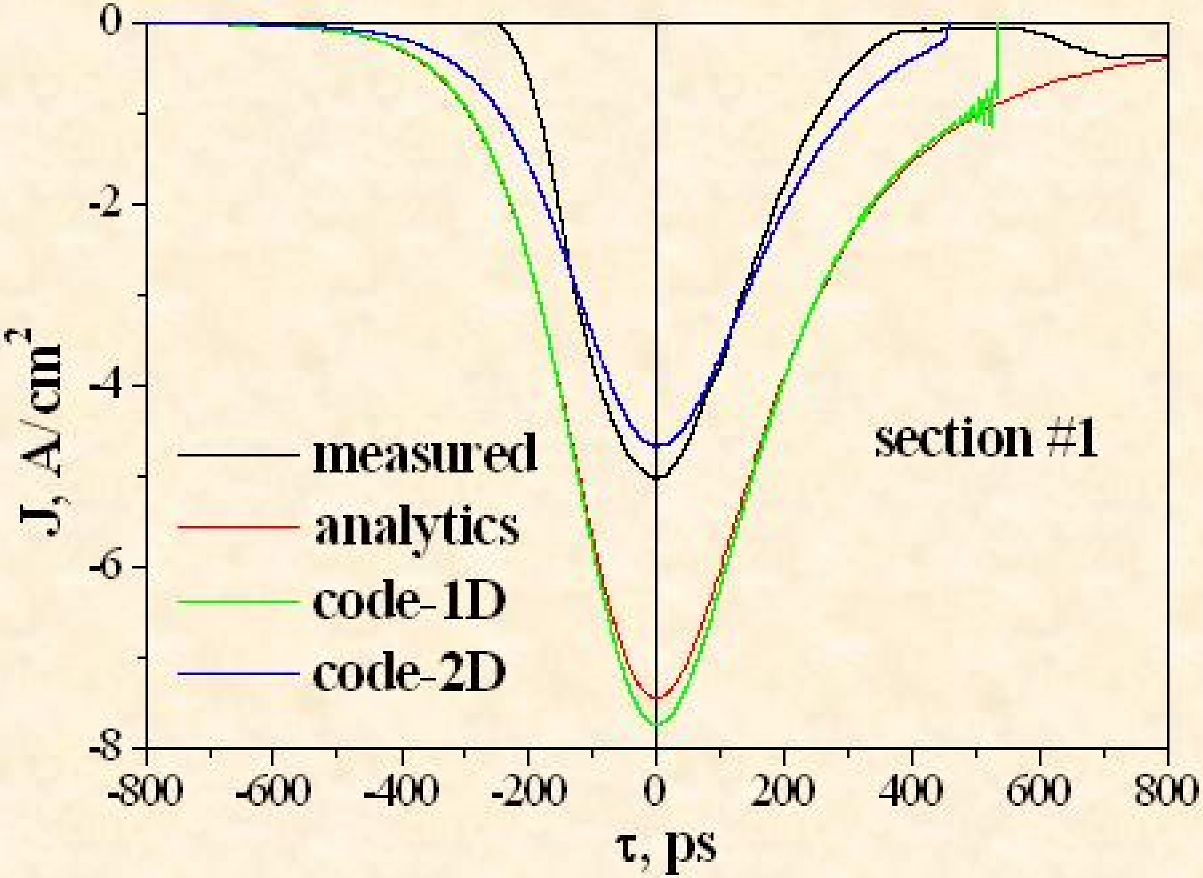


The time dependences of the electron current density I_r and emission current density in nonlinear mode (with space charge limitation)

Accelerated electron current density I_r vs emission current density

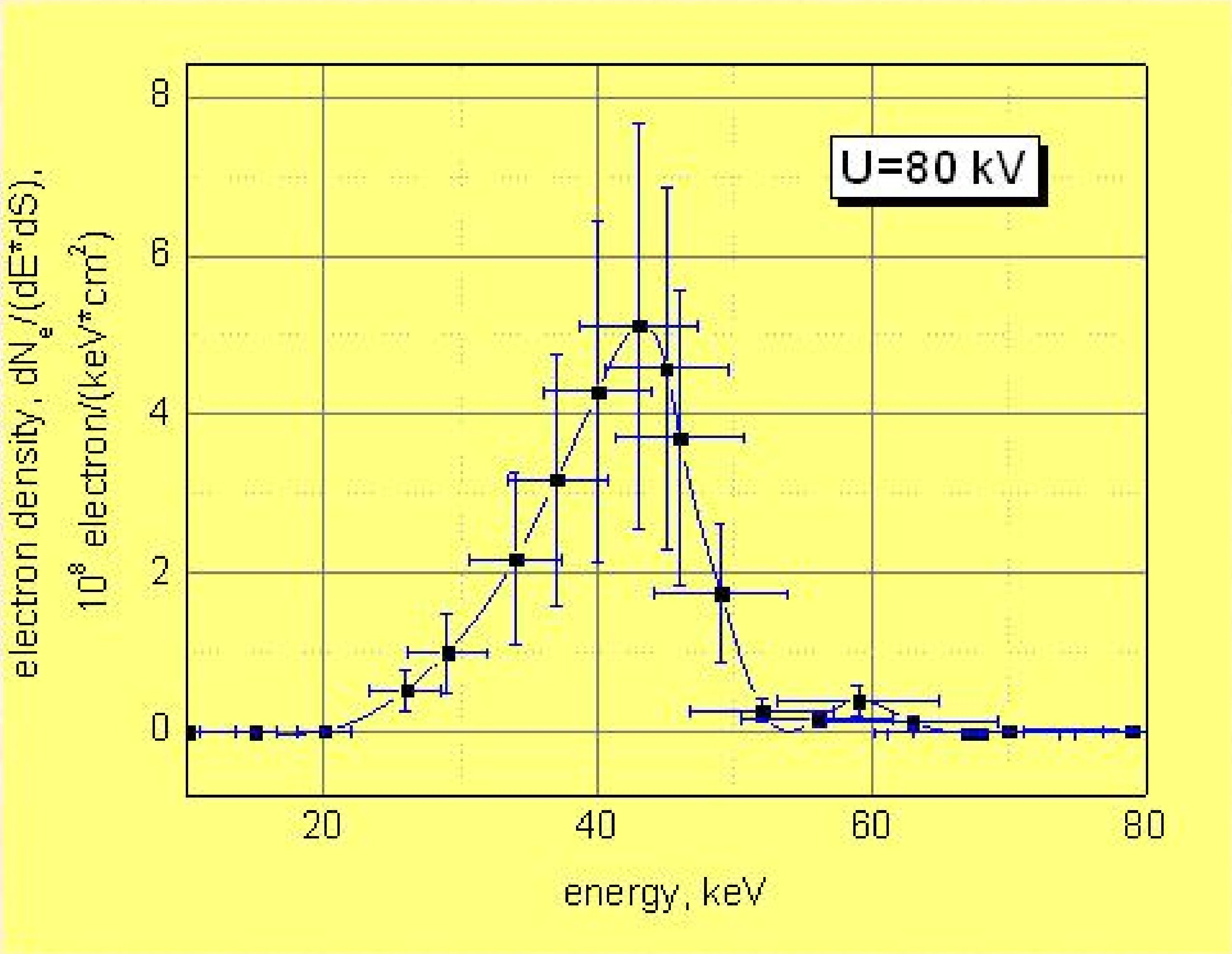


Comparison of Experimental & Theoretical Results



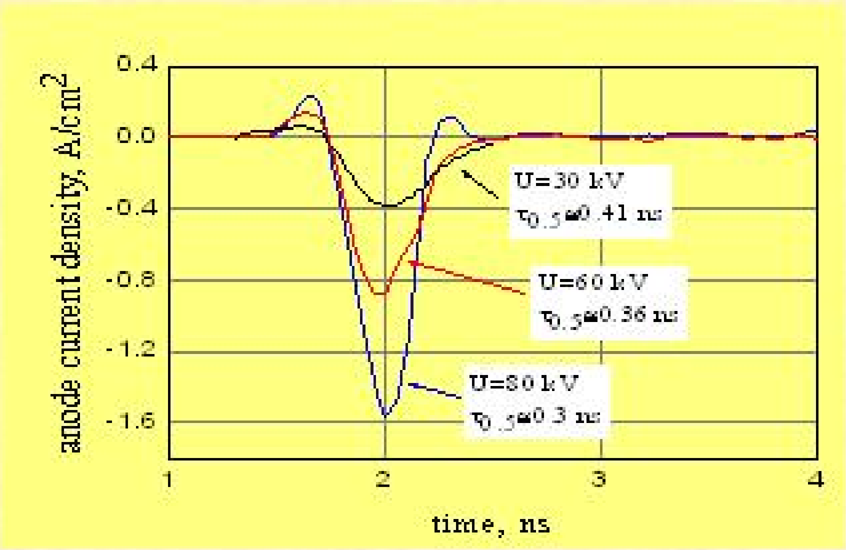
- **Anode current**

The spectrum of electrons, accelerated in a gap of the capacitor.
Measurement was executed with the help of electron spectrometer that operates according to a principle of 180° deviation of electrons in a constant magnetic field

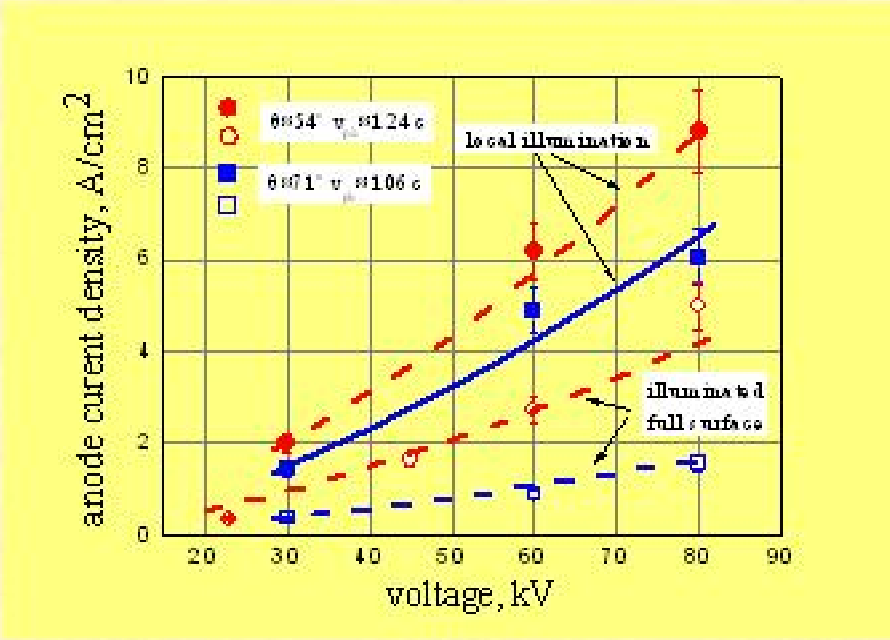


- Electrons accelerated in the diode had energy from 30 up to 60 keV though the voltage 80 kV was applied

The time dependence of the electron current density I_z (FC_1) for the voltage U changing across the capacitor



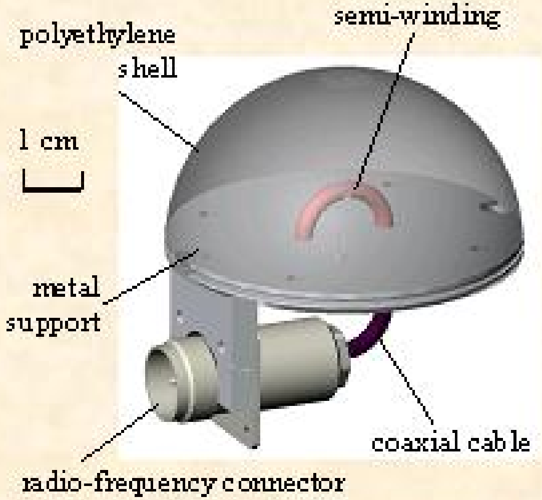
Electron current density I_z vs voltage U changing across the capacitor



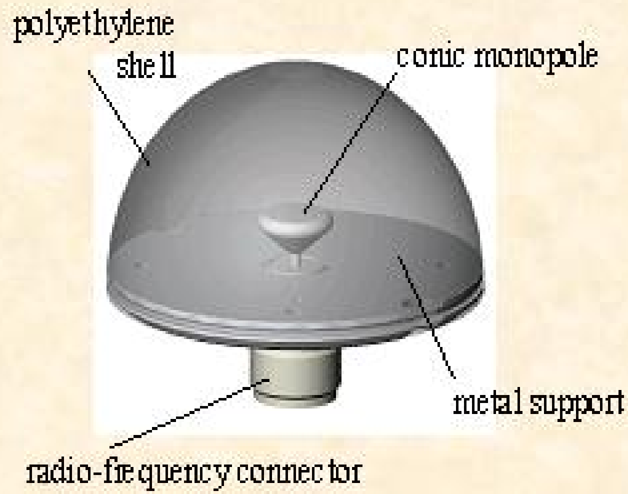
- With increase in a voltage duration of curent pulse decreases
- It was found out that the character of emission current dependence of the accelerated electron current depended on whether the diode was irradiated in a local manner or X-ray front passed along the whole of the cathode surface

EM sensors

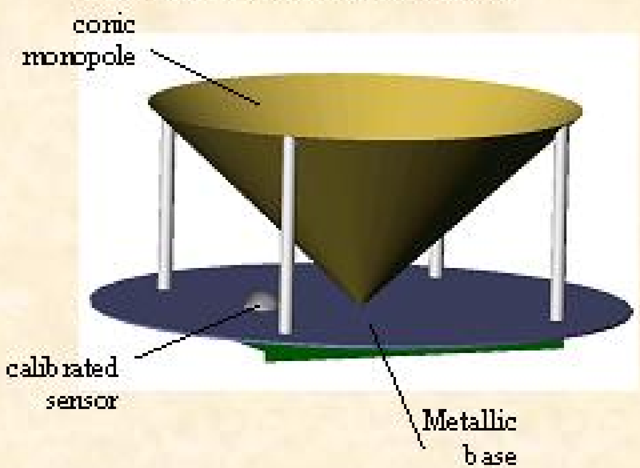
Design of magnetic field sensor
(Spiegel R.O., Booth C.A., Bronaugh E.L., 1983)



Design of capacitor antenna
(King R.W.R., 1983)



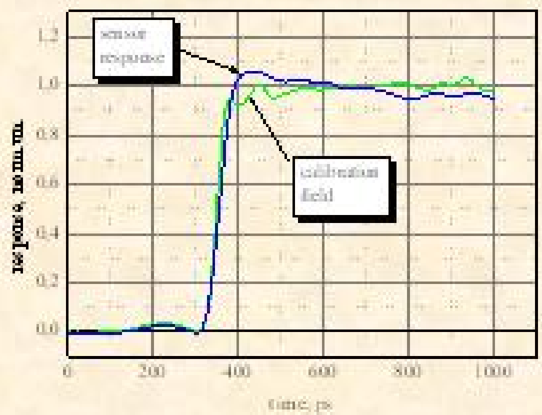
Calibration field table simulator



Calibration setup: step-generator - U_{max}≈5 V, $\tau_{0.1\text{-}0.9}$≤30 ps

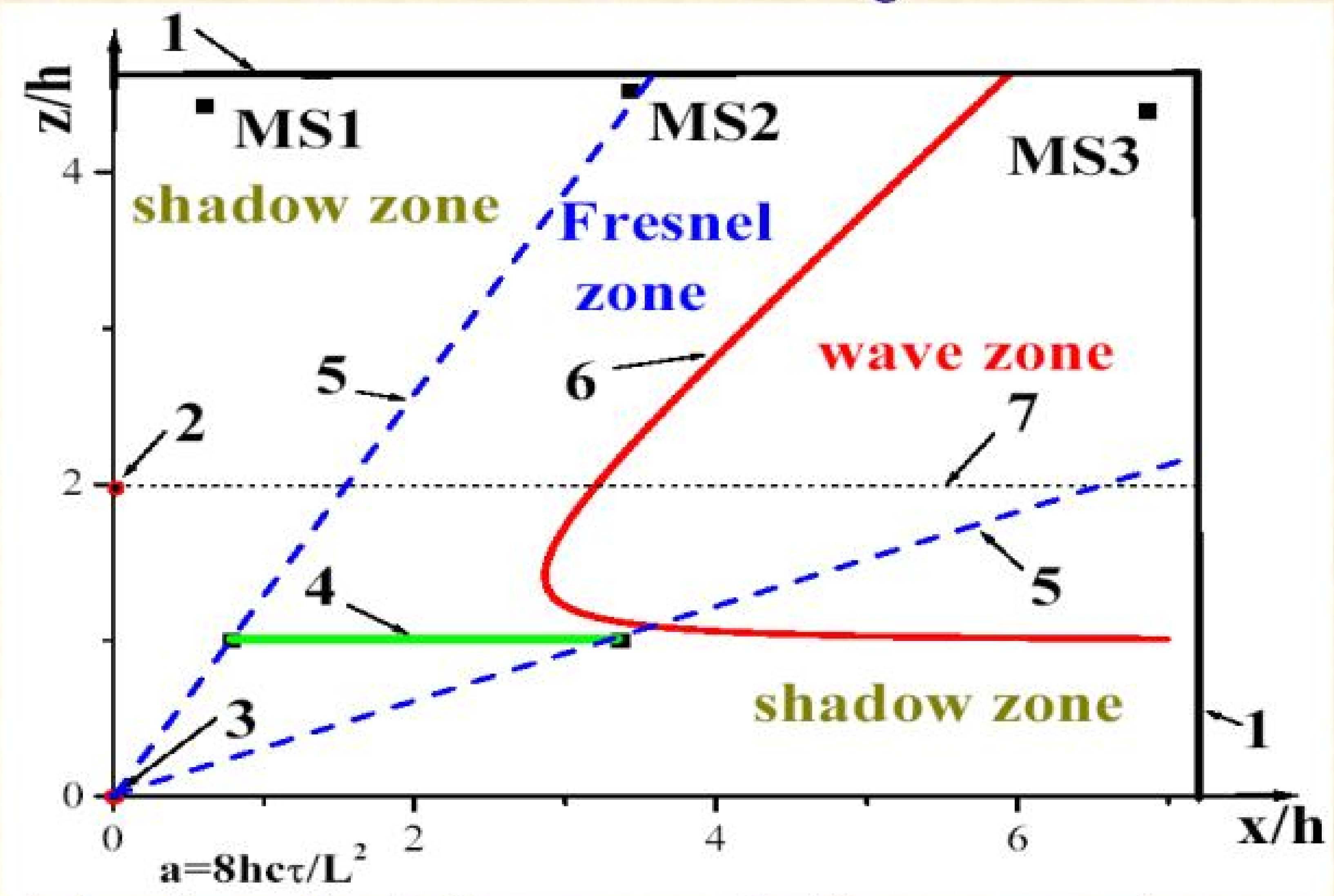
sampling oscilloscope bandwidth >12 GHz

Step response of field sensor



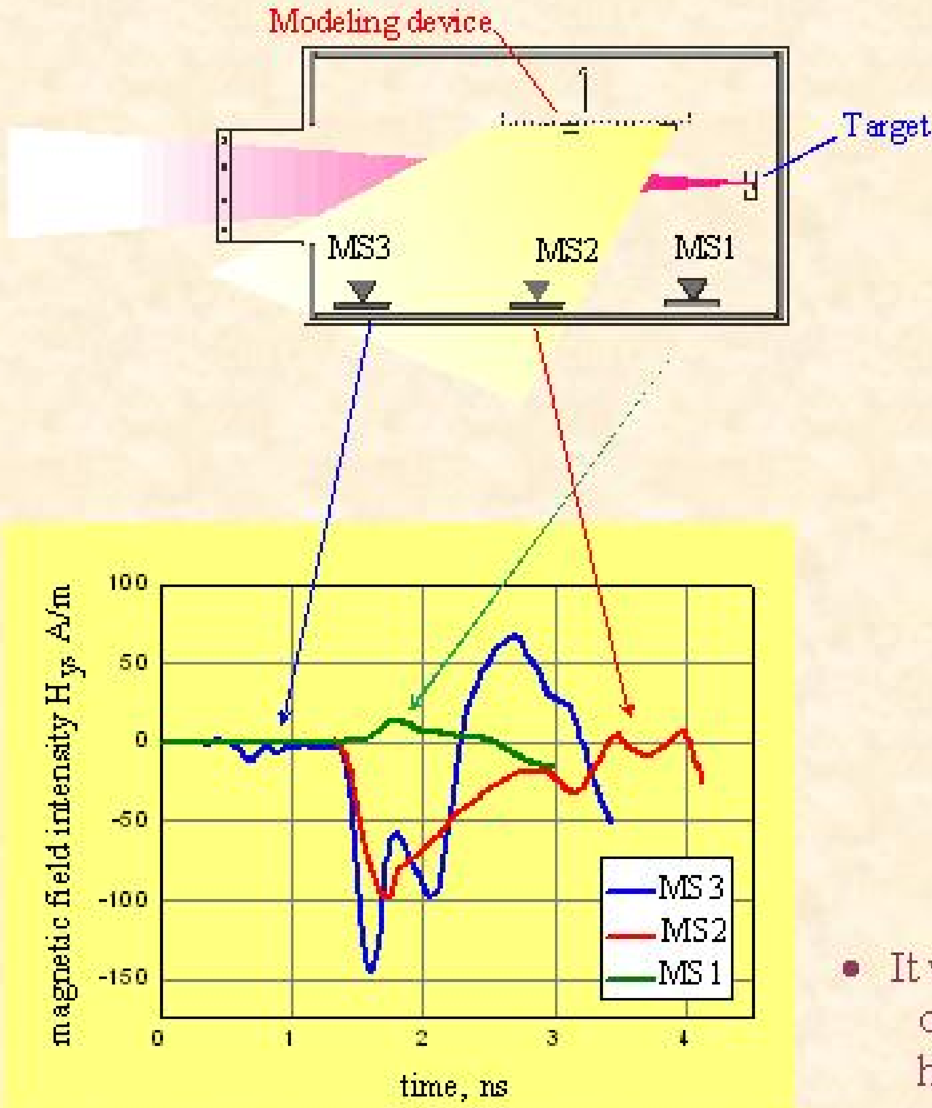
Rise time of field sensor τ_r<40 ps

Radiation zones diagram

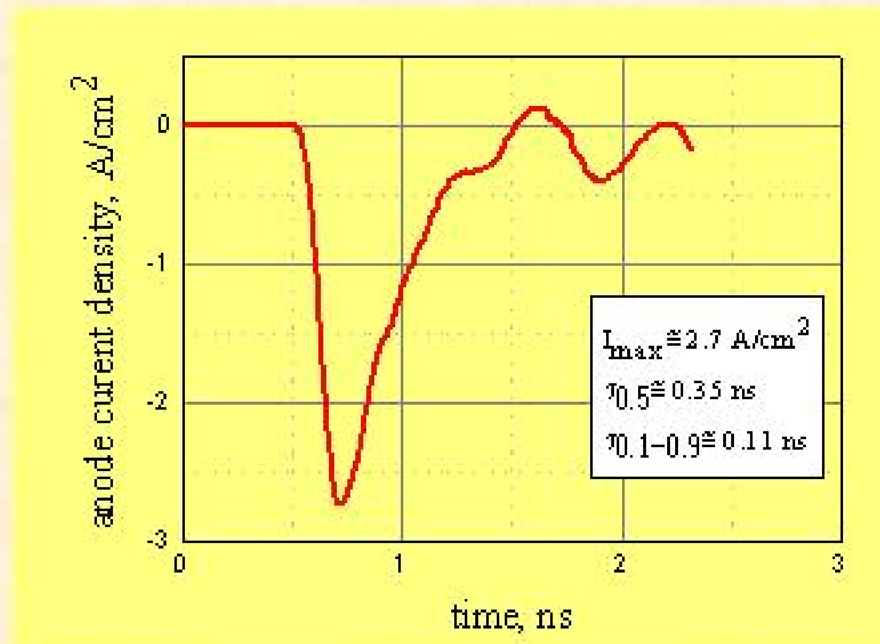


1-chamber walls, 2- X-ray source, 3 - X-ray source mirror image, 4 – diode, 5 – edge rays, 6 – wave zone boundary, 7 – laser axis

Time shape of magnetic field for different direction

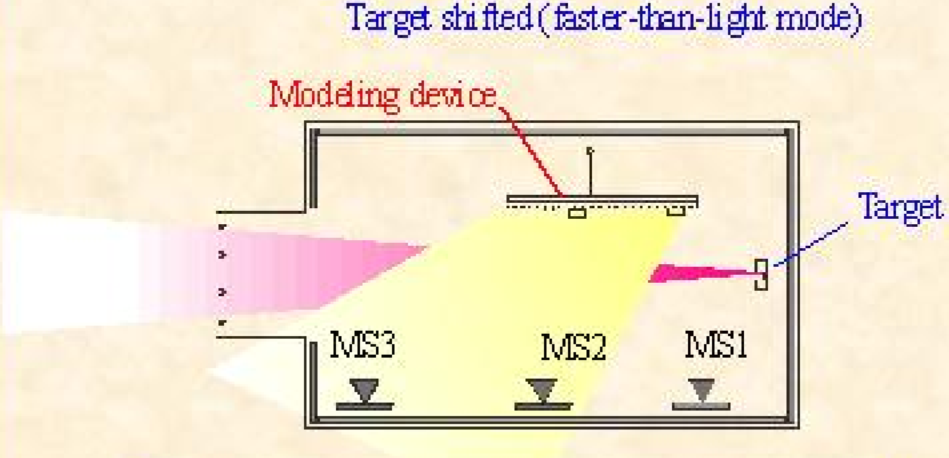


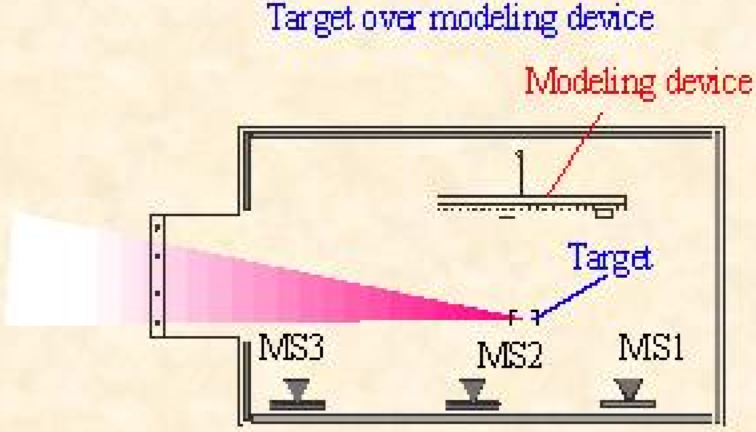
The time dependence of electron current density at the nearby edge of anode

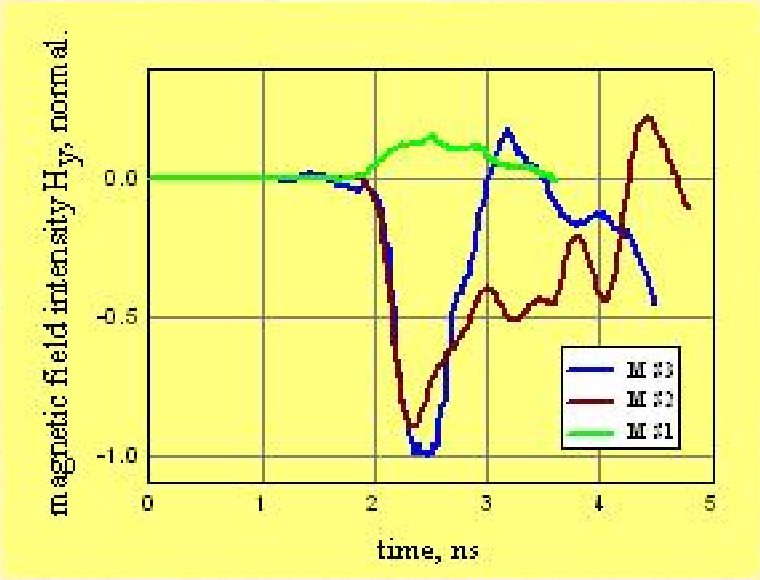


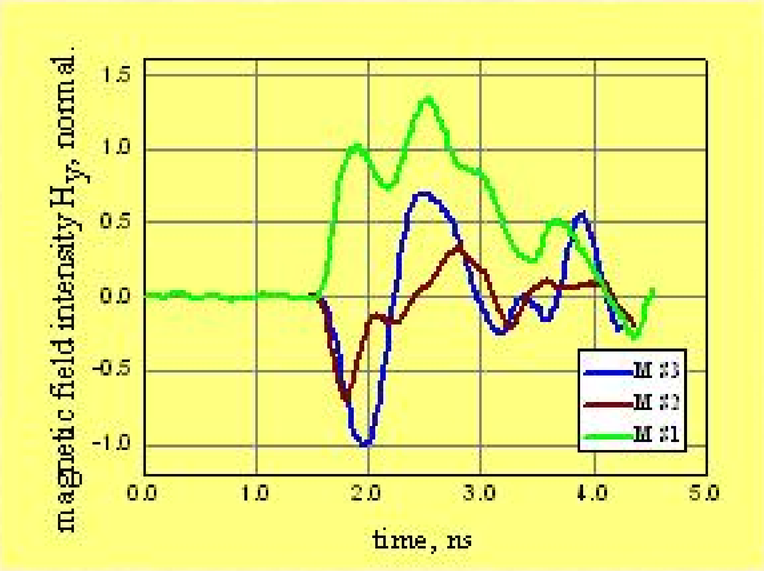
- It was experimentally established that radiation of the faster-than-light EMP source has a directed character

Time shape of magnetic field for different target location



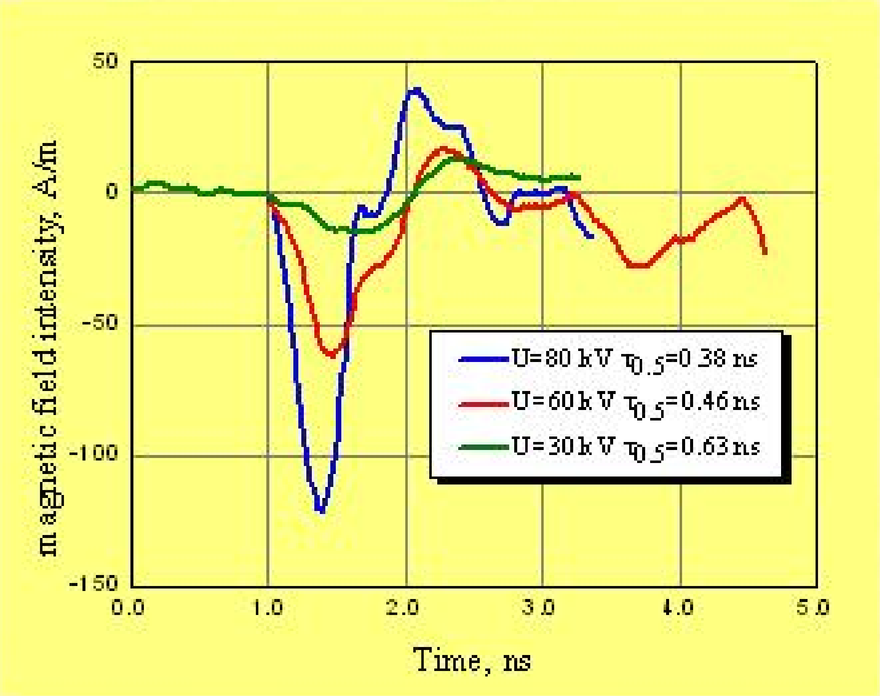




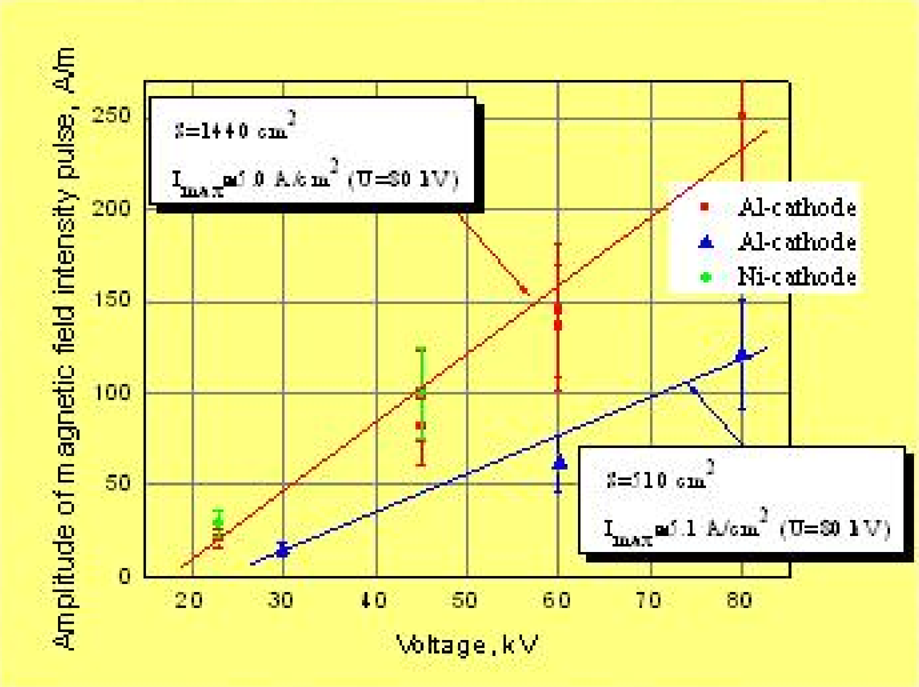


- At normal strike of the model device by X-ray the preferential direction of radiation was absent

The time dependence of the magnetic field H_Y (MS_3 direction) for the different diode voltage U

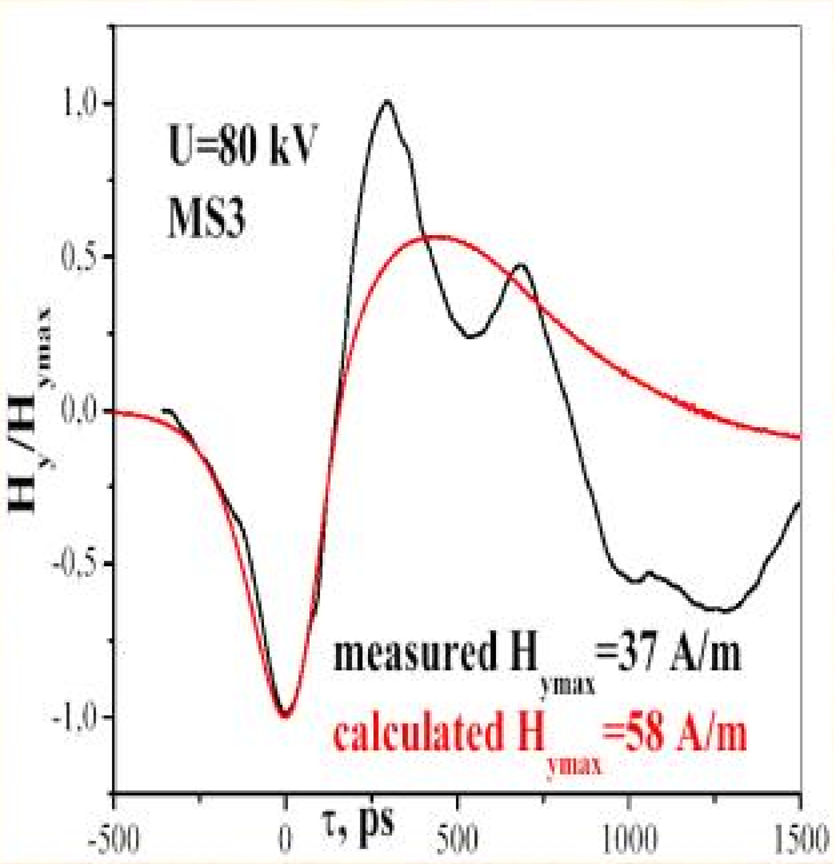


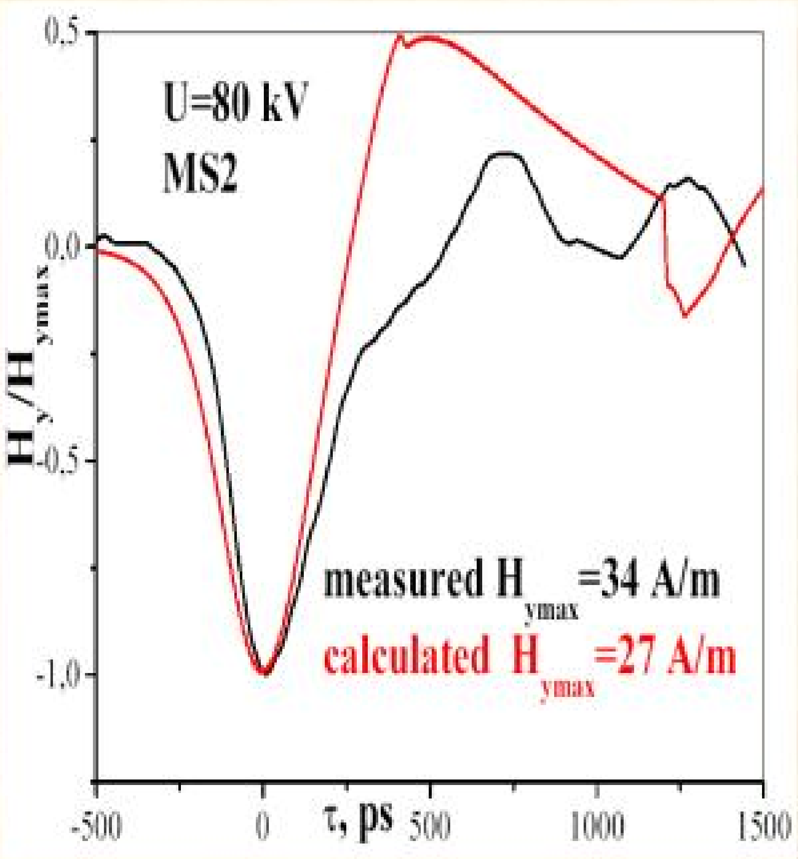
The dependence of the magnetic field amplitude H_Y (MS_3 direction) for the different diode voltage U



- With growth of the applied voltage the first phase EMP as well as current pulse is shortened
- It was shown that the amplitude of the first phase of EMP changed approximately as U
- It was found out that increase of diode square led to approximately proportionally increase of the field amplitude

Comparison of Experimental & Theoretical Results





Conclusions

- EMP from faster-than-light source was studied experimentally
- Direct-like EM radiation pattern was found
- EM pulse with ~ 100 kV/m amplitude and ~ 250 ps rise-time at distance of 3 m from source was detected (diode voltage is 80 kV)
- EMP amplitude dependence on diode voltage is stronger than linear
- Diode current decreasing due to diode electromagnetic insulation was proved experimentally