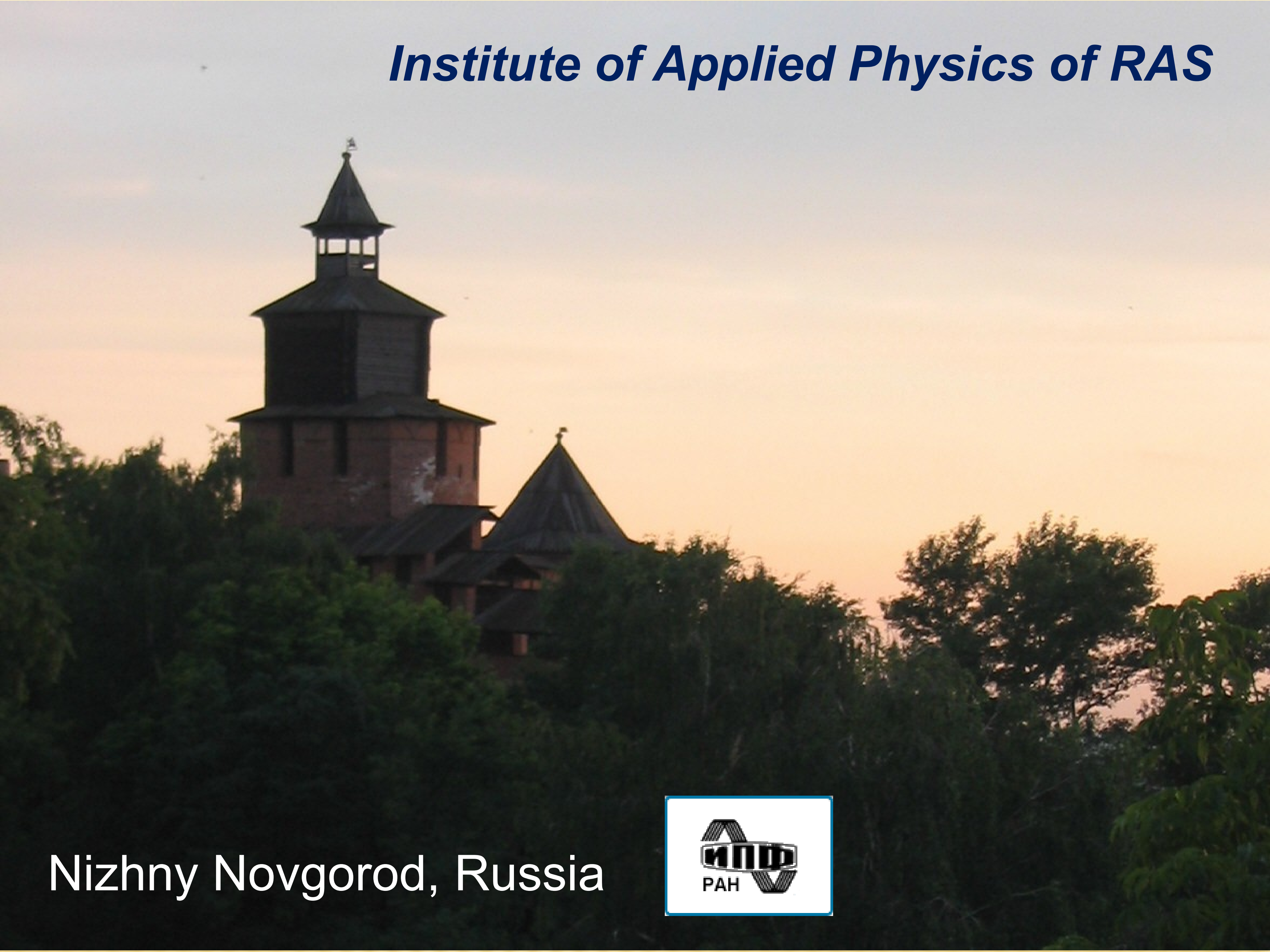
Institute of Applied Physics of RAS



Nizhny Novgorod, Russia

ИПФ РАН

MICROPULSES GENERATION IN ECR BREAKDOWN STIMULATED BY GYROTRON RADIATION

V. Zorin, V.Skalyga, I. Izotov, S. Golubev,
S. Razin, A. Sidorov, A. Vodopyanov

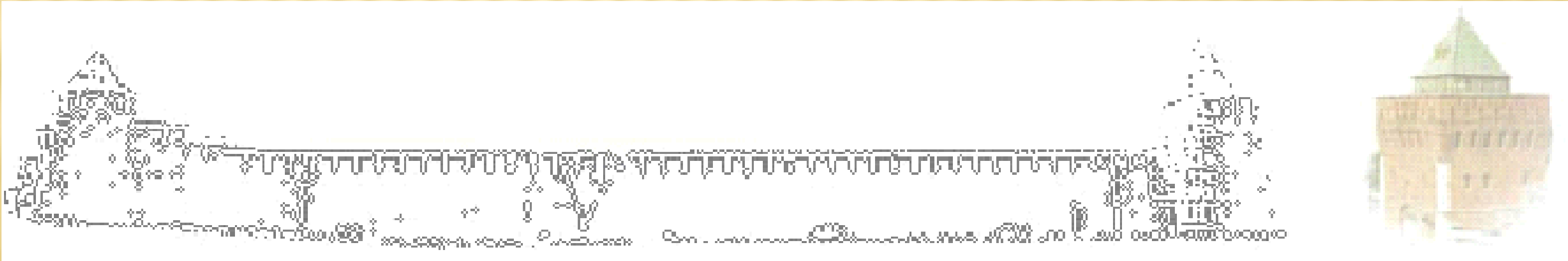
Outline

1. Study of pulse mode operation:

- Motivations
- Experimental results
- Simulations

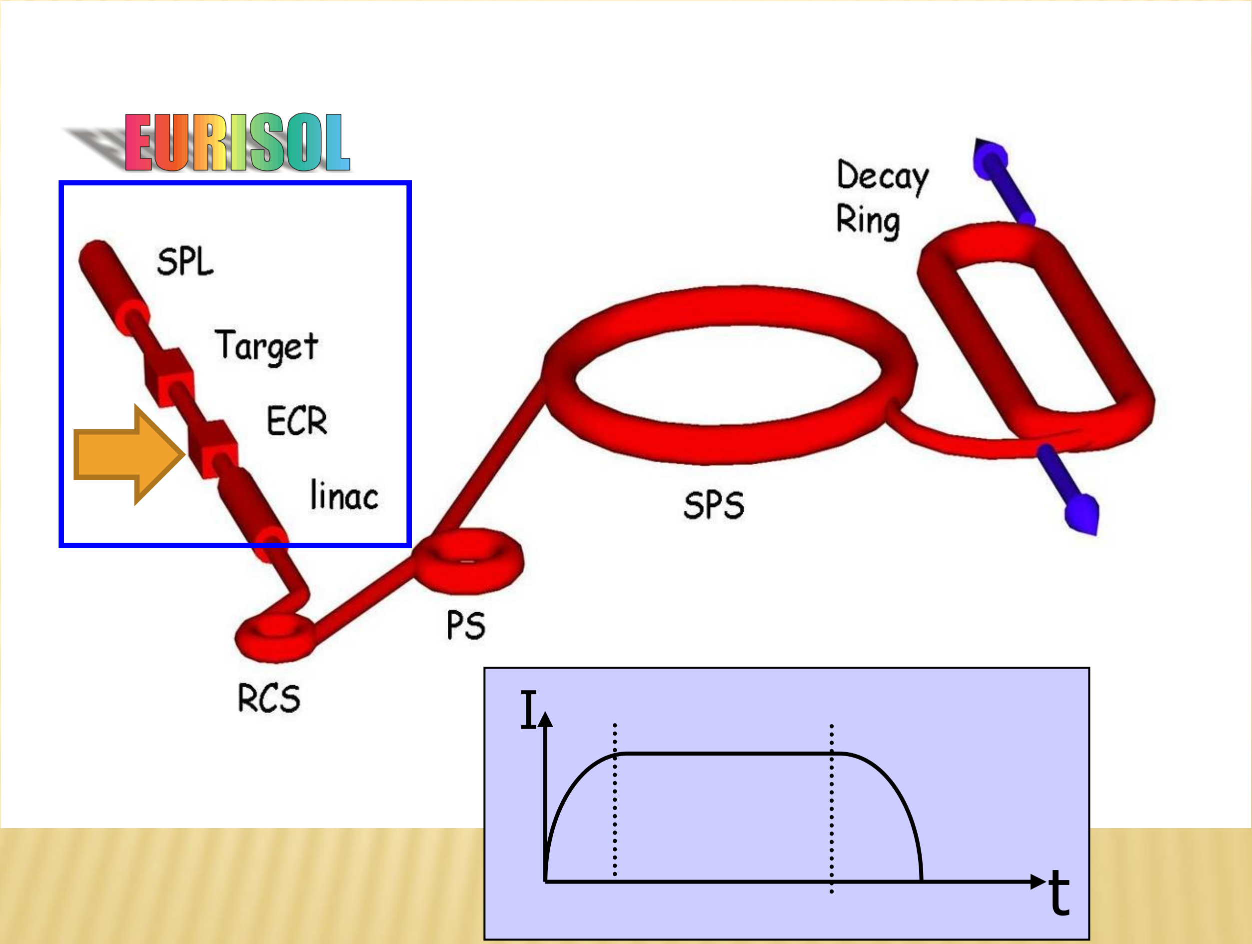
2. Unexpected:

- Fantasy



MOTIVATION: CERN, BETA BEAM, AND EURISOL

- Short pulse MCI source (20-100 μs)



Decay ring

B = 5 T

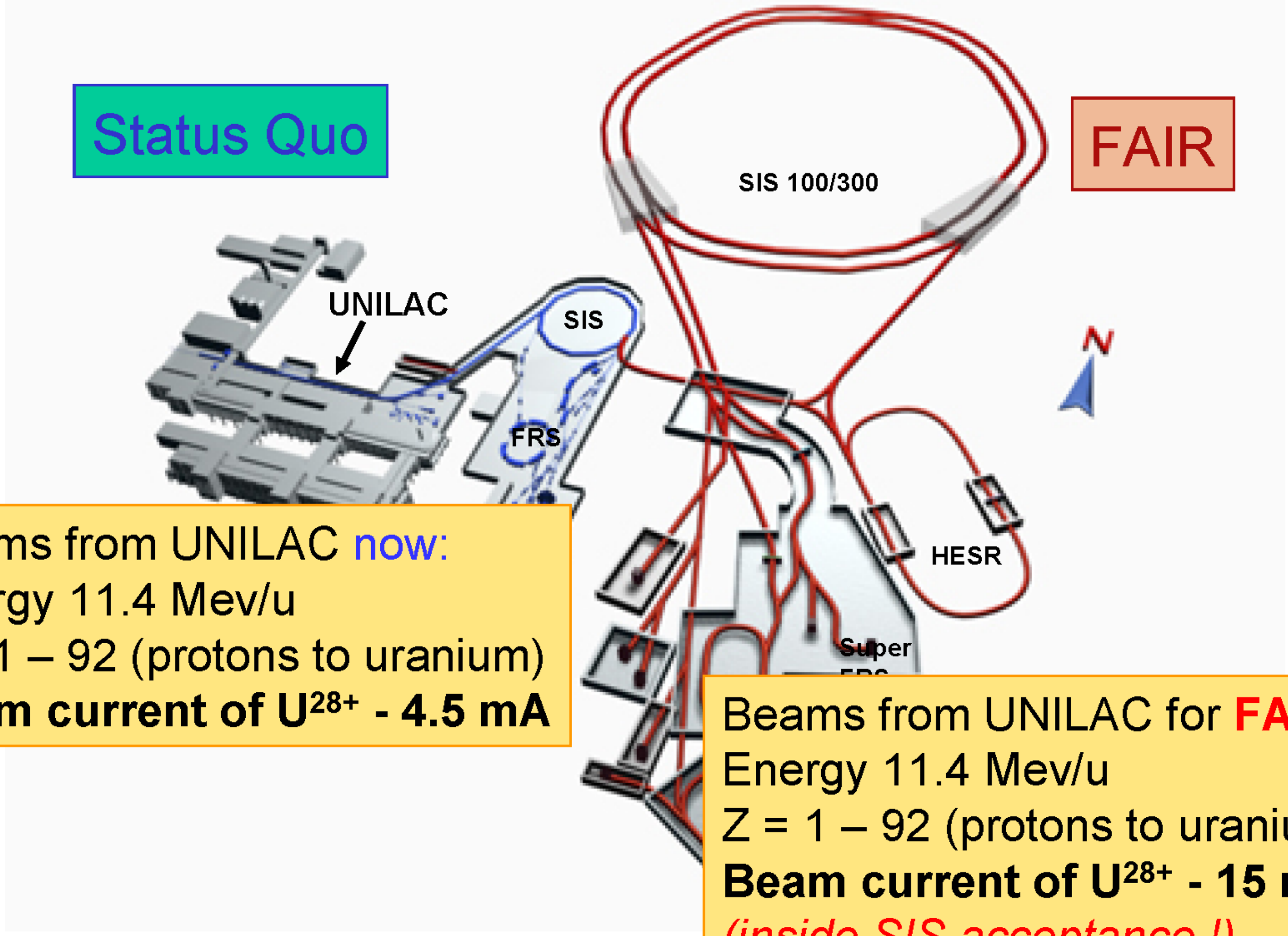
L_{ss} = 2500 m

$^{6}_{2}He \rightarrow ^{6}_{3}Li\, e^{-} \bar{\nu}$

$^{18}_{10}Ne \rightarrow ^{18}_{9}F\, e^{+} \nu$

MOTIVATION: FAIR PROJECT, GSI

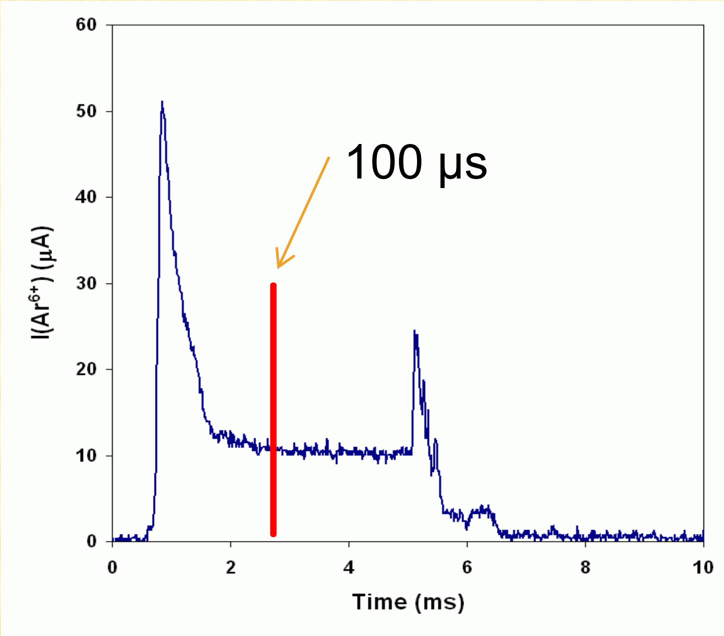
Future International Accelerator Facility at GSI:
FAIR (Facility for Antiproton and Ion Research)



Beams from UNILAC now:
Energy 11.4 Mev/u
Z = 1 – 92 (protons to uranium)
Beam current of U^{28+} - 4.5 mA

Beams from UNILAC for **FAIR**
Energy 11.4 Mev/u
Z = 1 – 92 (protons to uranium)
Beam current of U^{28+} - 15 mA
(inside SIS acceptance !)

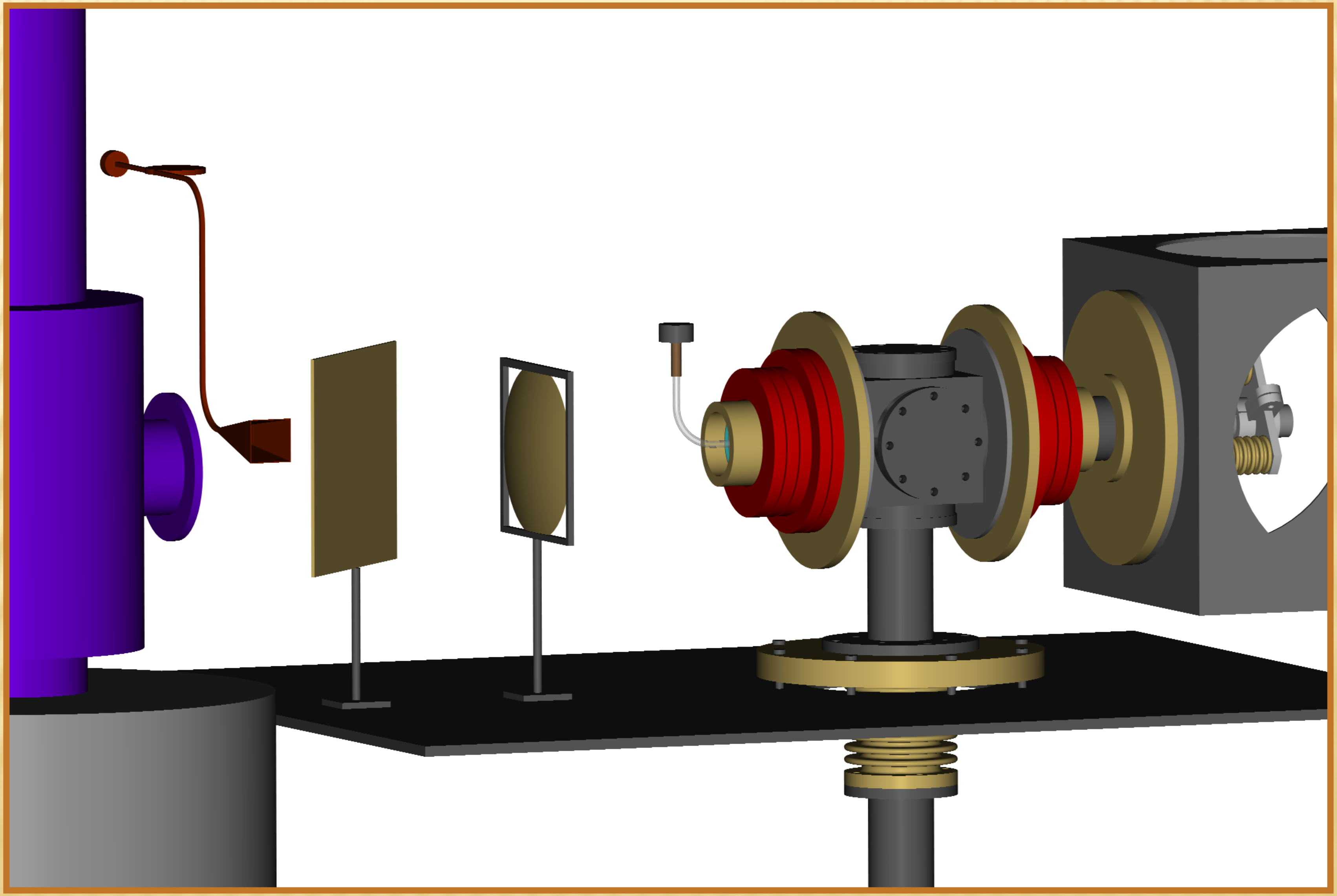
REQUIREMENTS FROM BETA BEAM PROJECT



28 GHz
Grenoble
T. Lamy at al

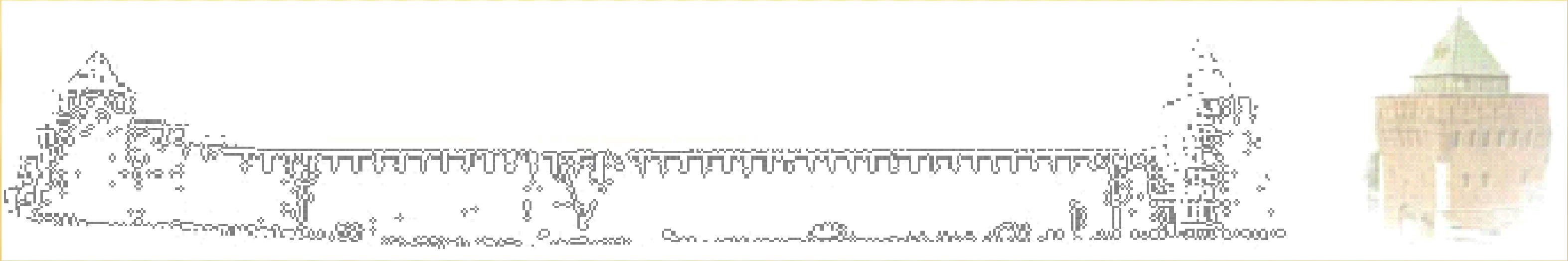
- Is it possible to reduce pulse duration?

NIZHNY NOVGOROD EXPERIMENTAL SETUP, 37 GHz

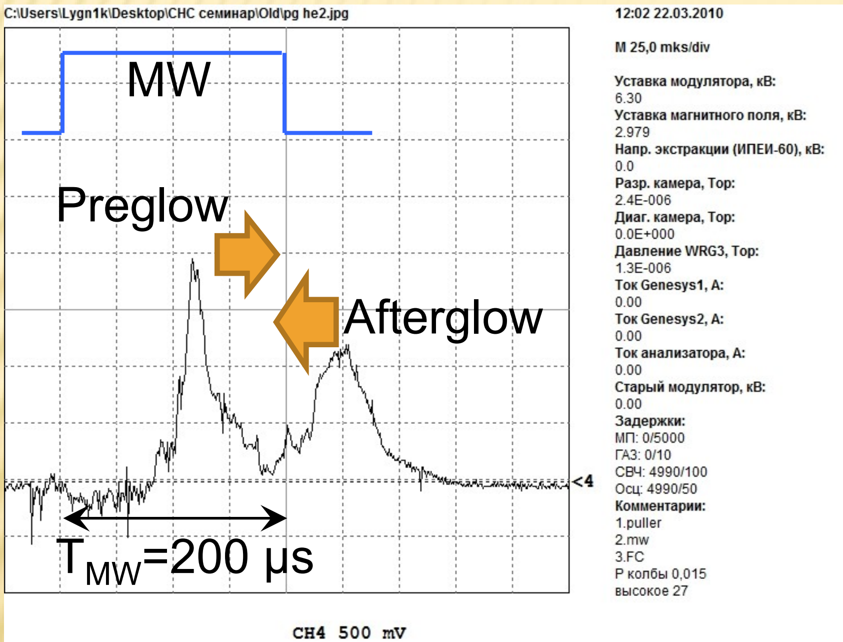


PECULIARITIES OF EXPERIMENTS

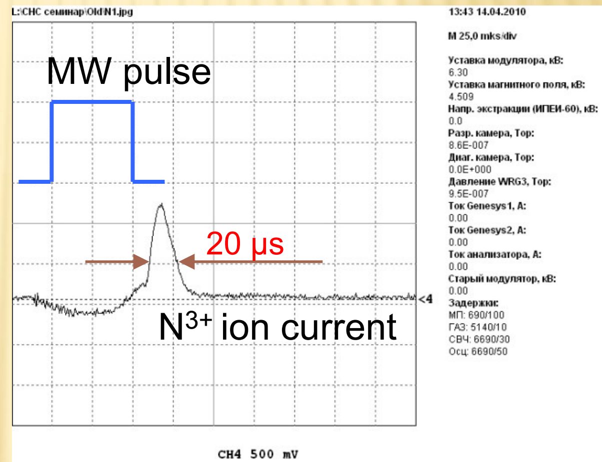
- Just a mirror trap
- High frequency of microwaves – 37 GHz
- Short pulses of microwaves
- Flexible design



Preglow, 37 GHz

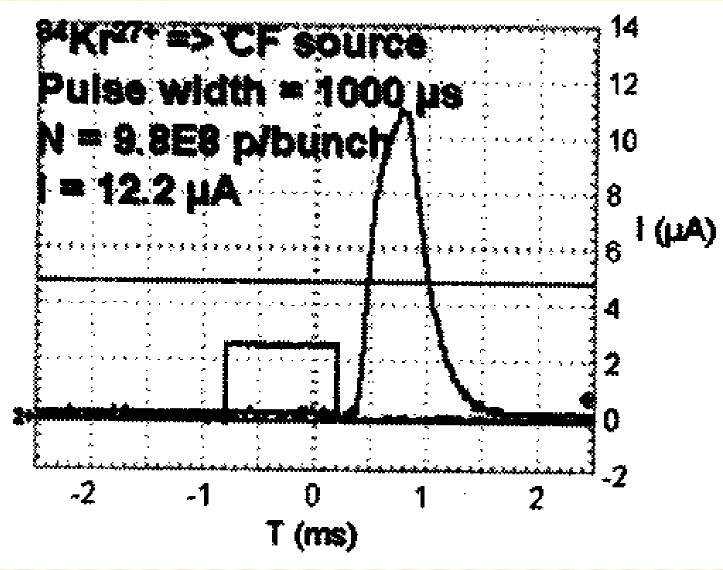


50 μs per division



MW duration = 50 μs
Ion current pulse duration = 20 μs
N^{3+} ion current = 2 мА

GANIL's work

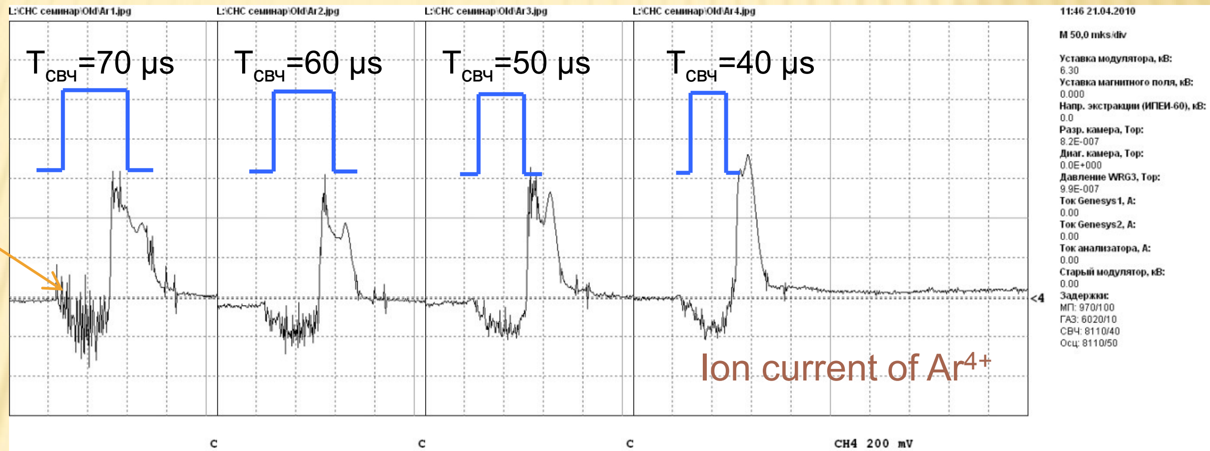


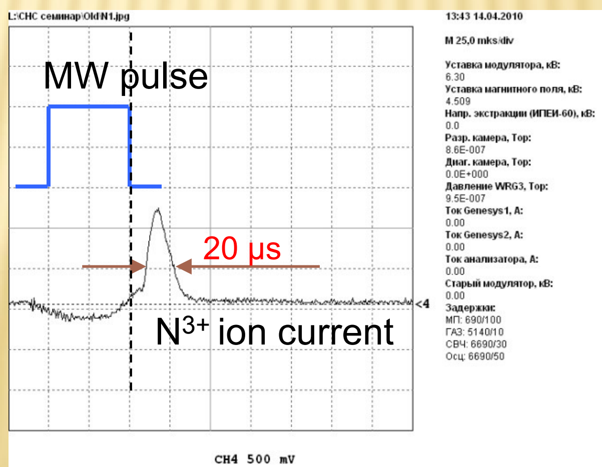
L. Maunoury at all
Rev. of Scient. Instr. 79, 02A313 (2008)

SHORT PULSES, EXPERIMENTS, 37 GHz

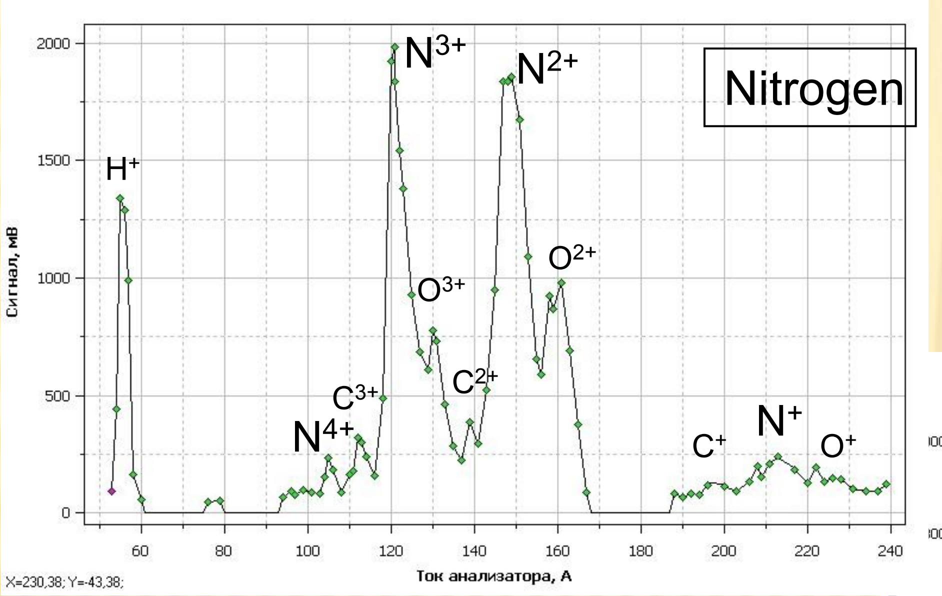
Duration of ion current vs microwave duration

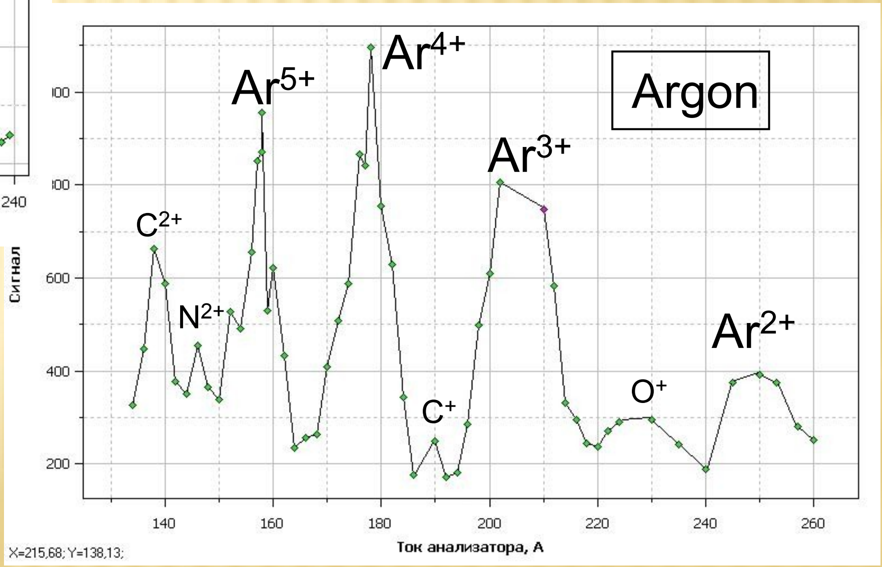
Just noise





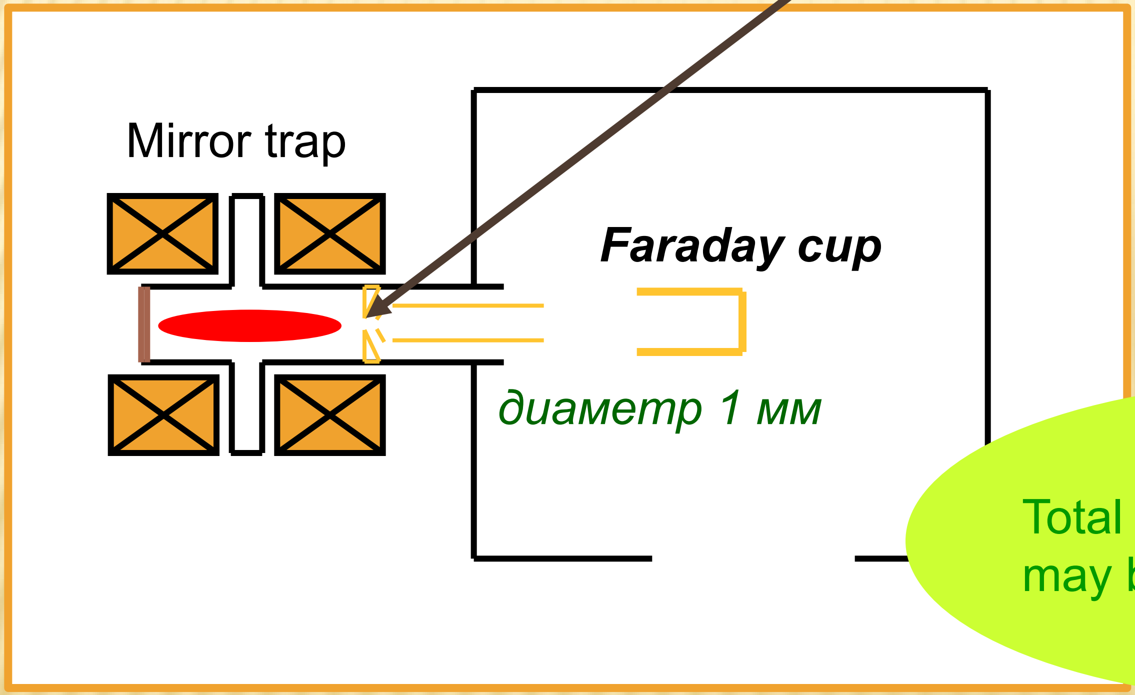
CHARGE STATE DISTRIBUTION IN SHORT PULSES





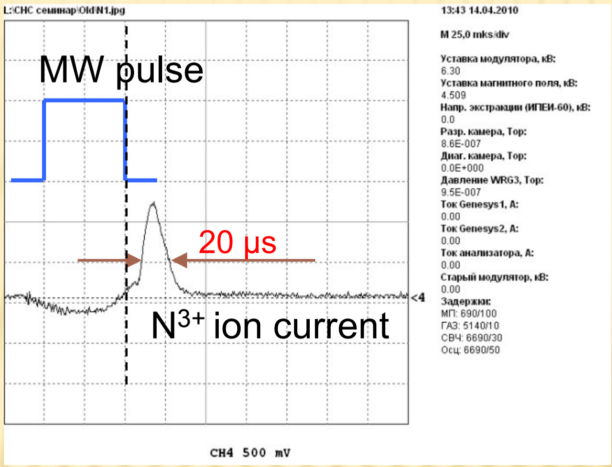
ION CURRENT DENSITY

70 - 100 мА/см ^{2}

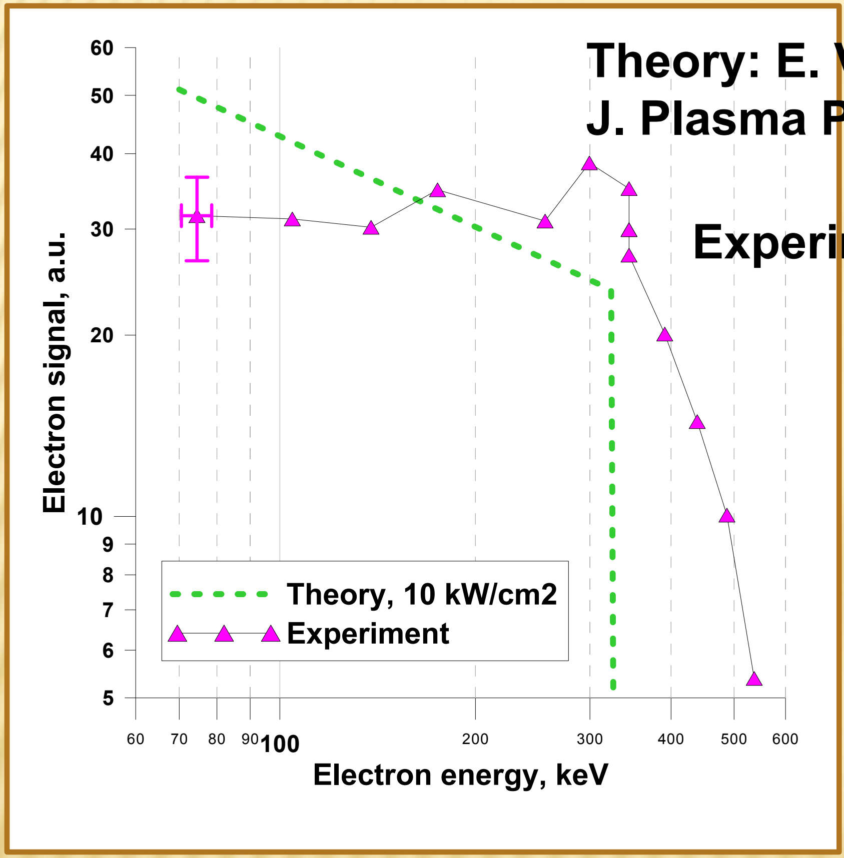


Total ion current more 100 mA may be reached.

Explanation of the temporal evolution

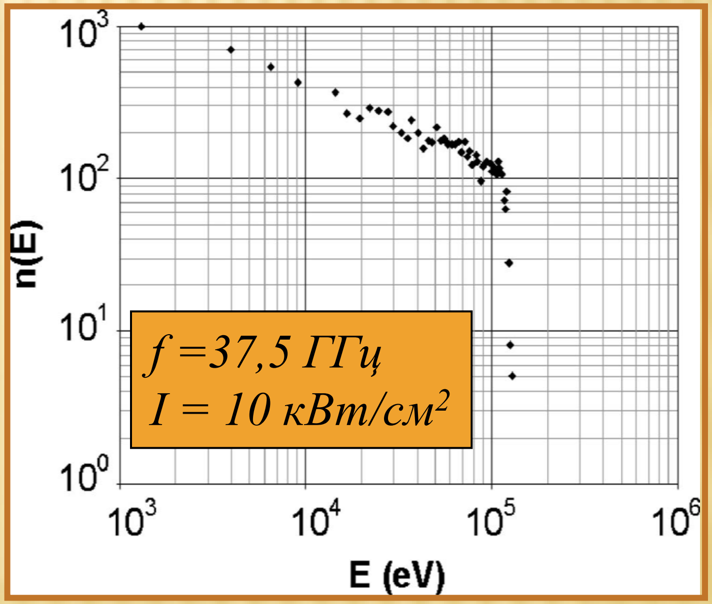


ELECTRON DISTRIBUTION FUNCTION



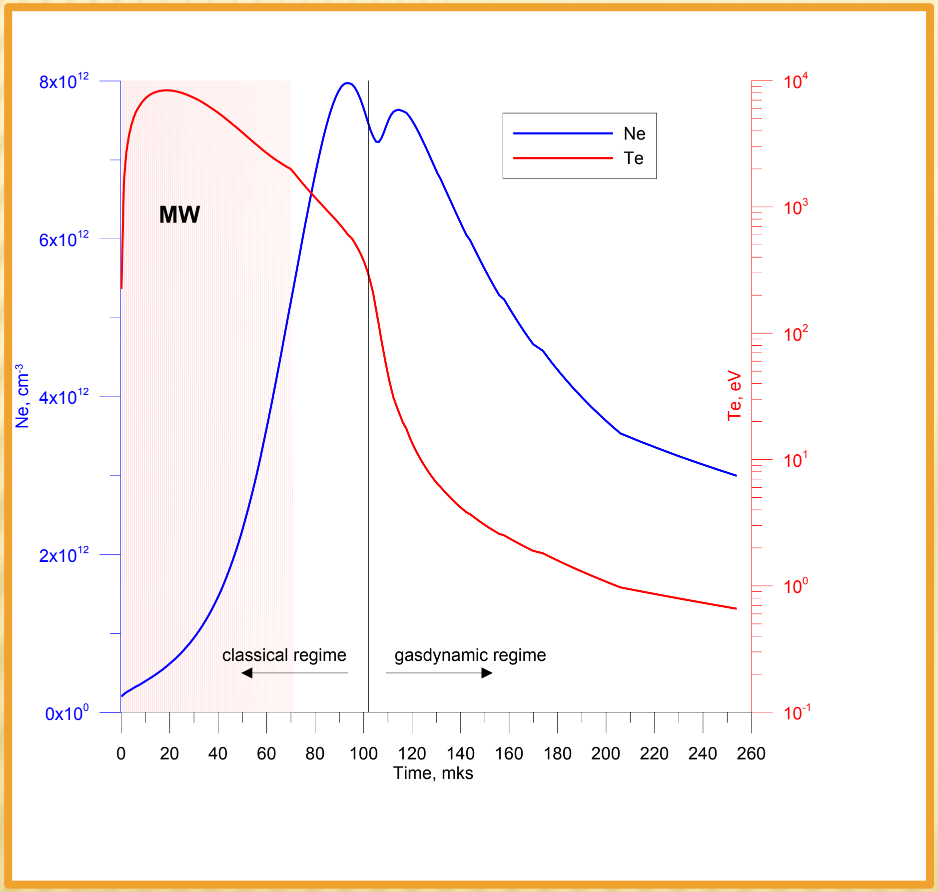
Theory: E. V. Suvorov and M. D. Tokman, Sov. J. Plasma Phys. 15, 540 (1989).

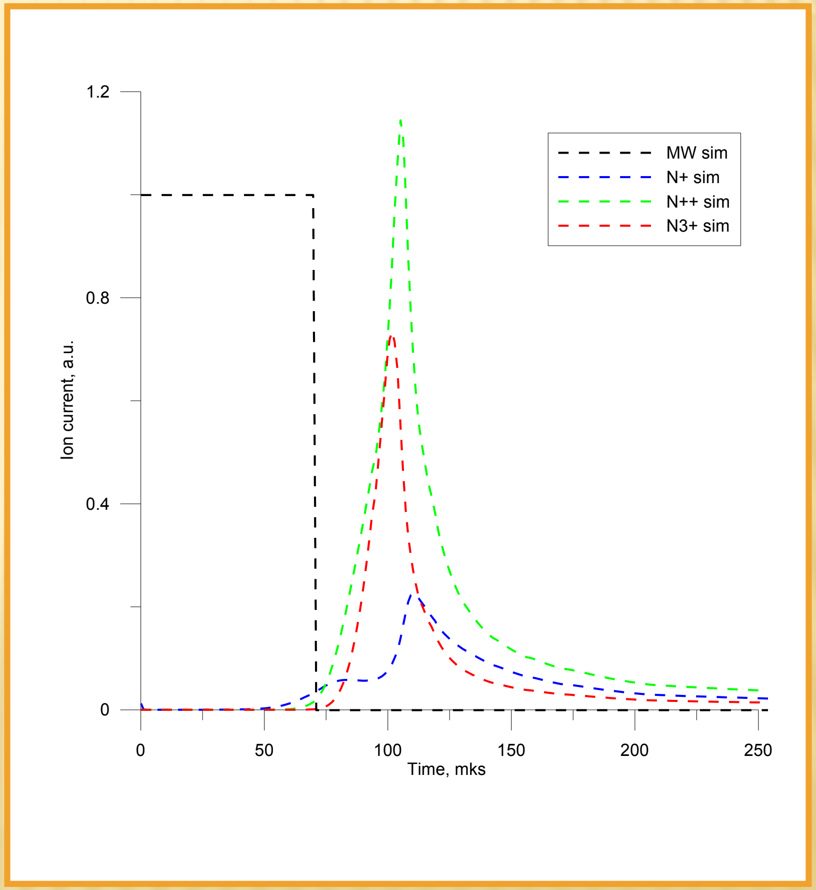
Experiment: IAP RAS, 2010, not published .



Numerical simulation by V. Erukhimov

Simulation of micropulses



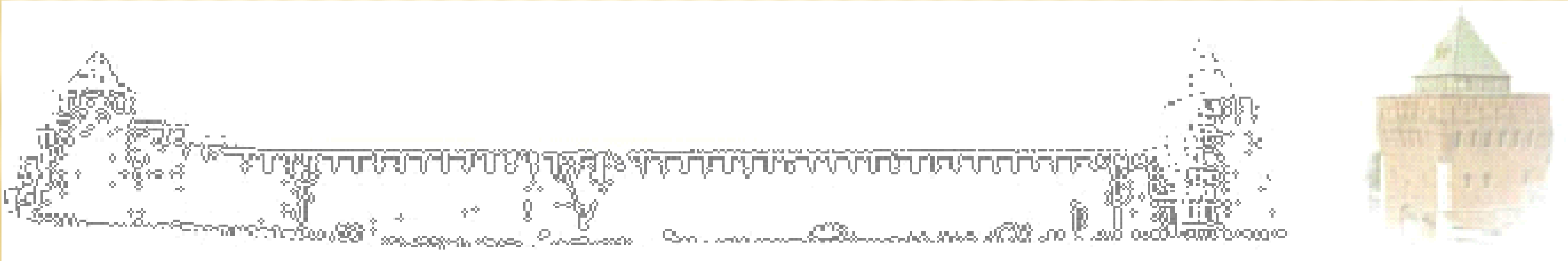


CONCLUSION

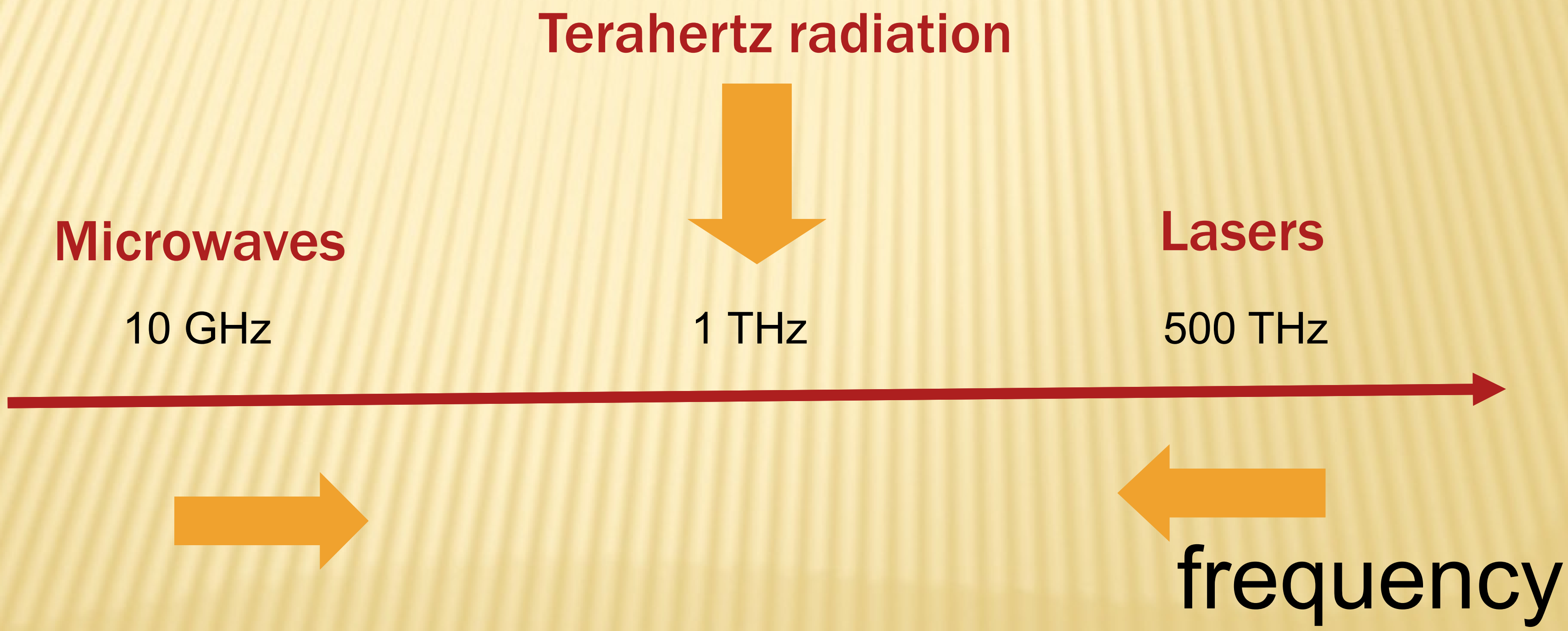
- Multicharged ion beam was obtained with pulse duration as short as required.
- Higher pumping frequency – higher charge
- 75 GHz experiments will be done in 2010 - 2011

High frequency – dream of ECR community

Reality and fantasies

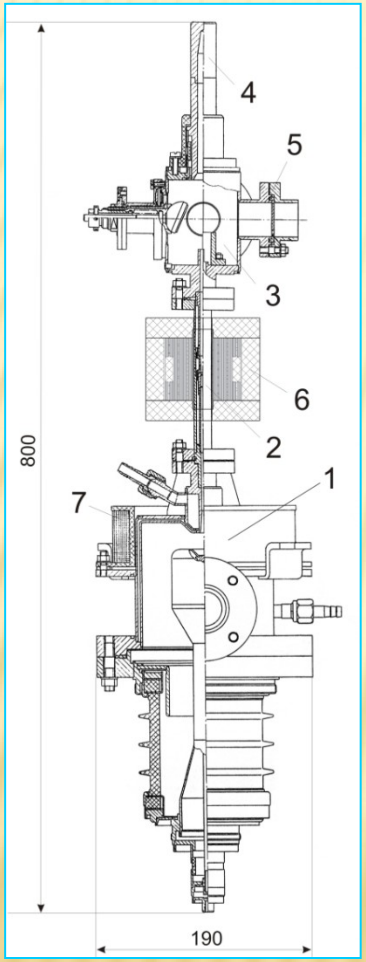


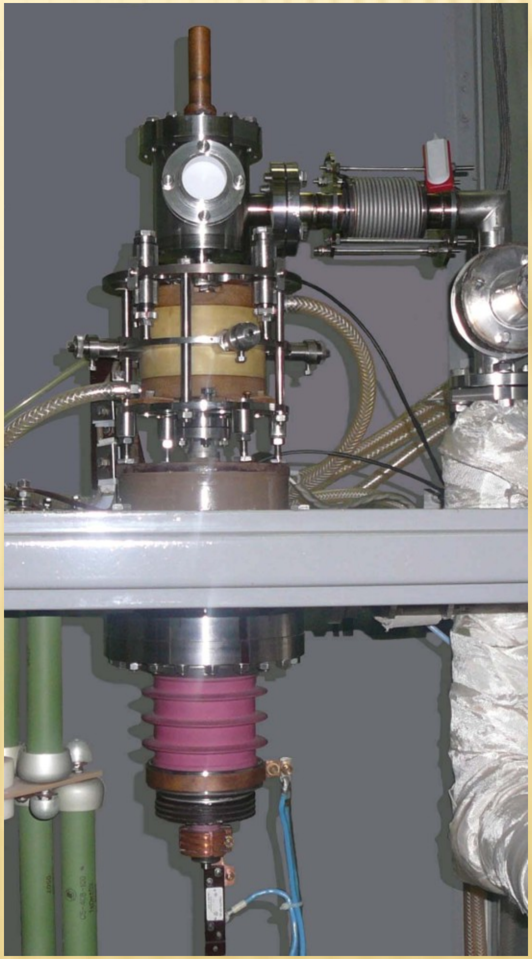
Ion sources


Terahertz radiation
Microwaves
Lasers
10 GHz
1 THz
500 THz
frequency

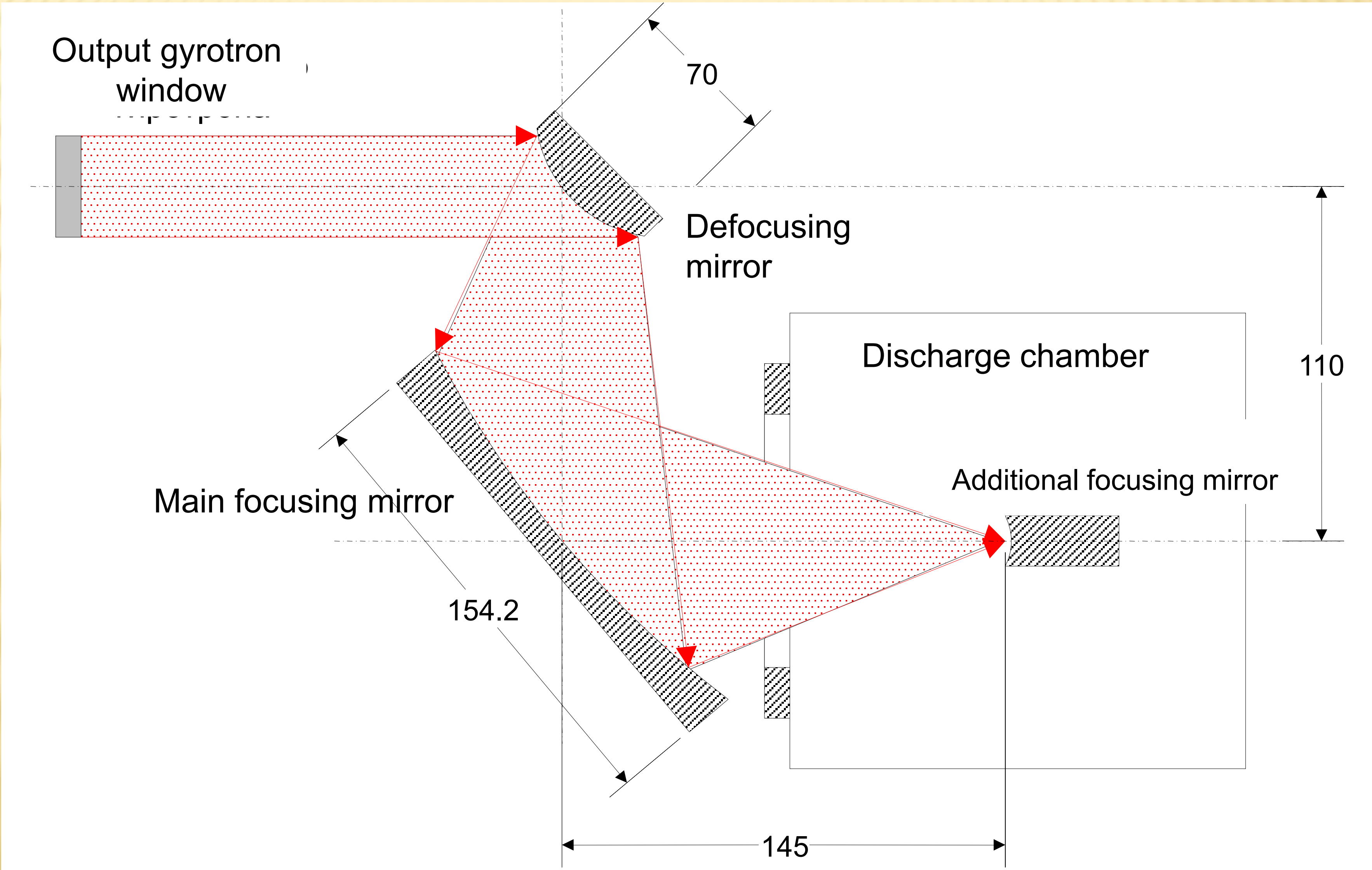
Reality:

Gyrotron: f = 0.55-1 THz, T=7 μs, W~400 W

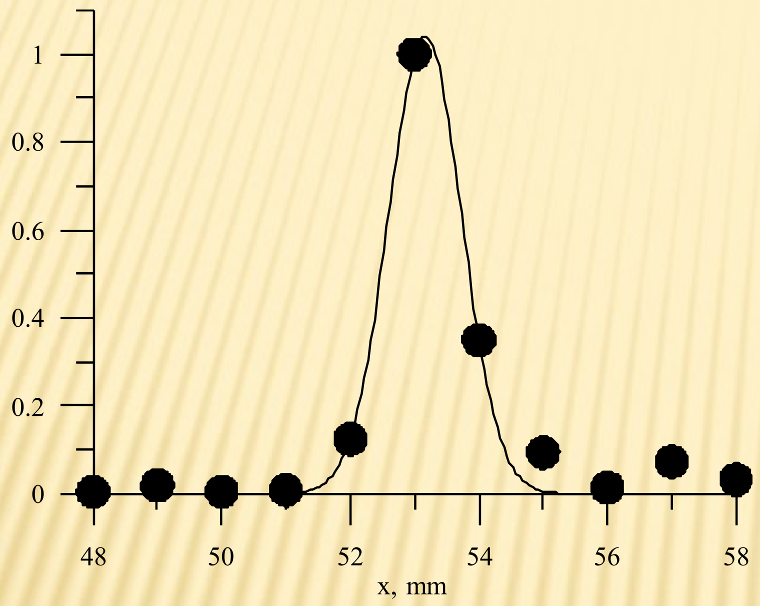


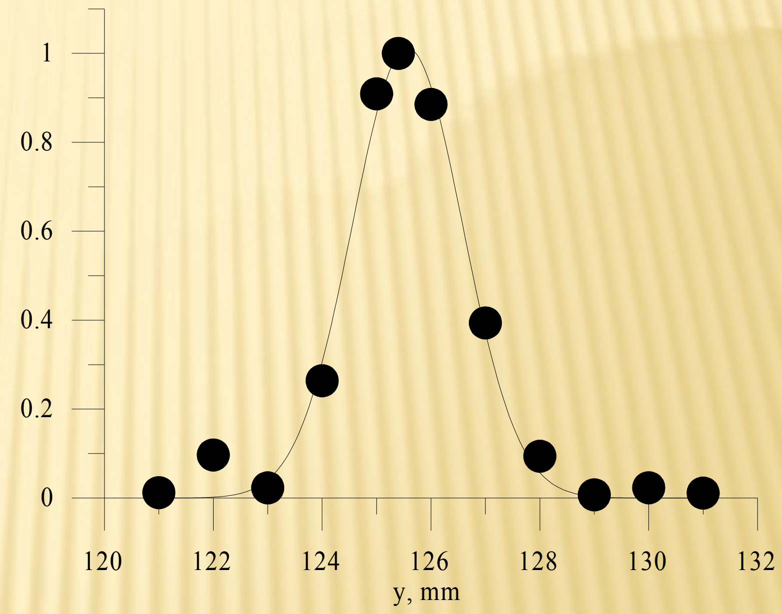


THz beam focusing for 0,55 THz



Wave beam in focus of the main mirror

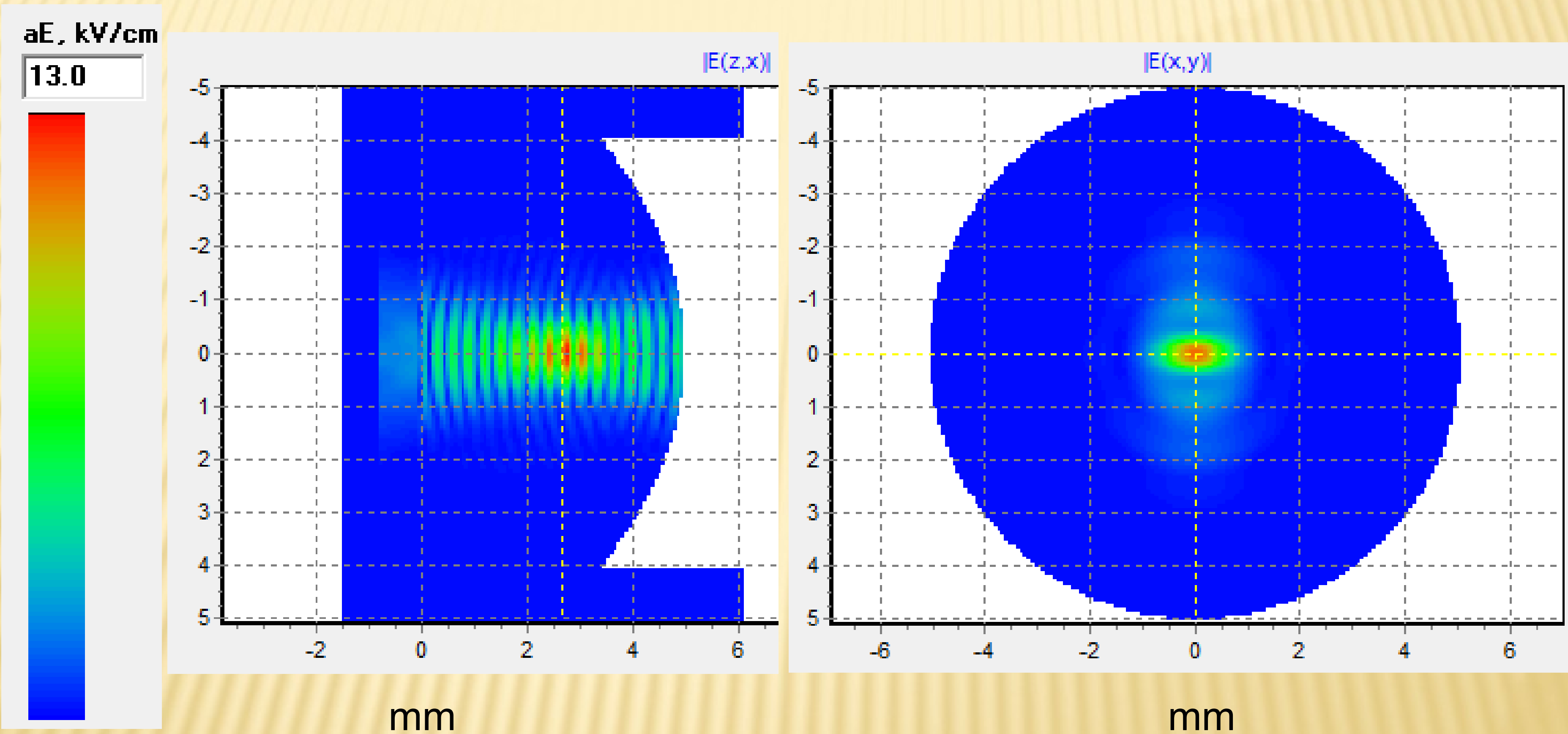




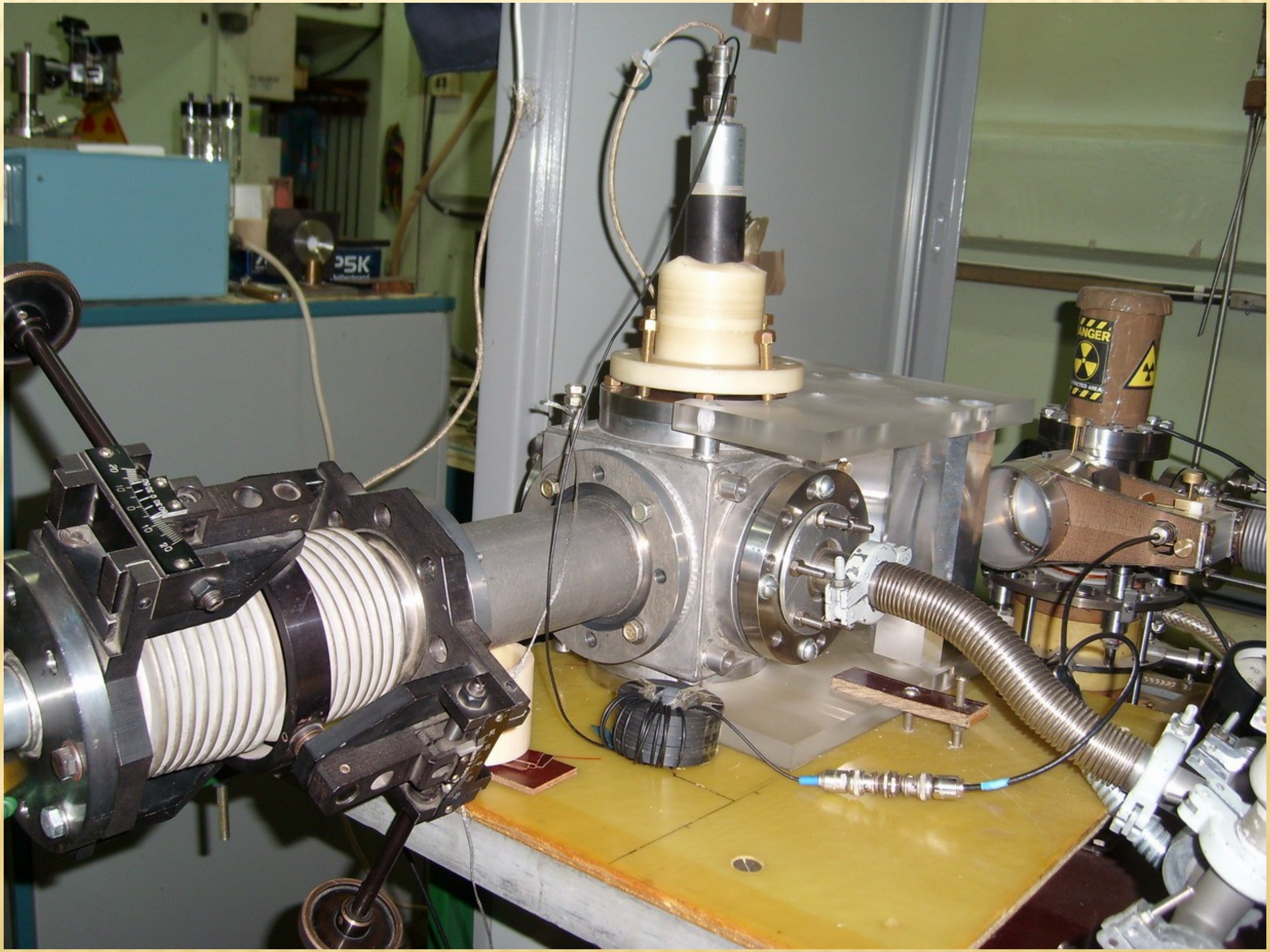
Beam dimension: 2,1x3,7 λ^2

THz power density is enough for plasma heating

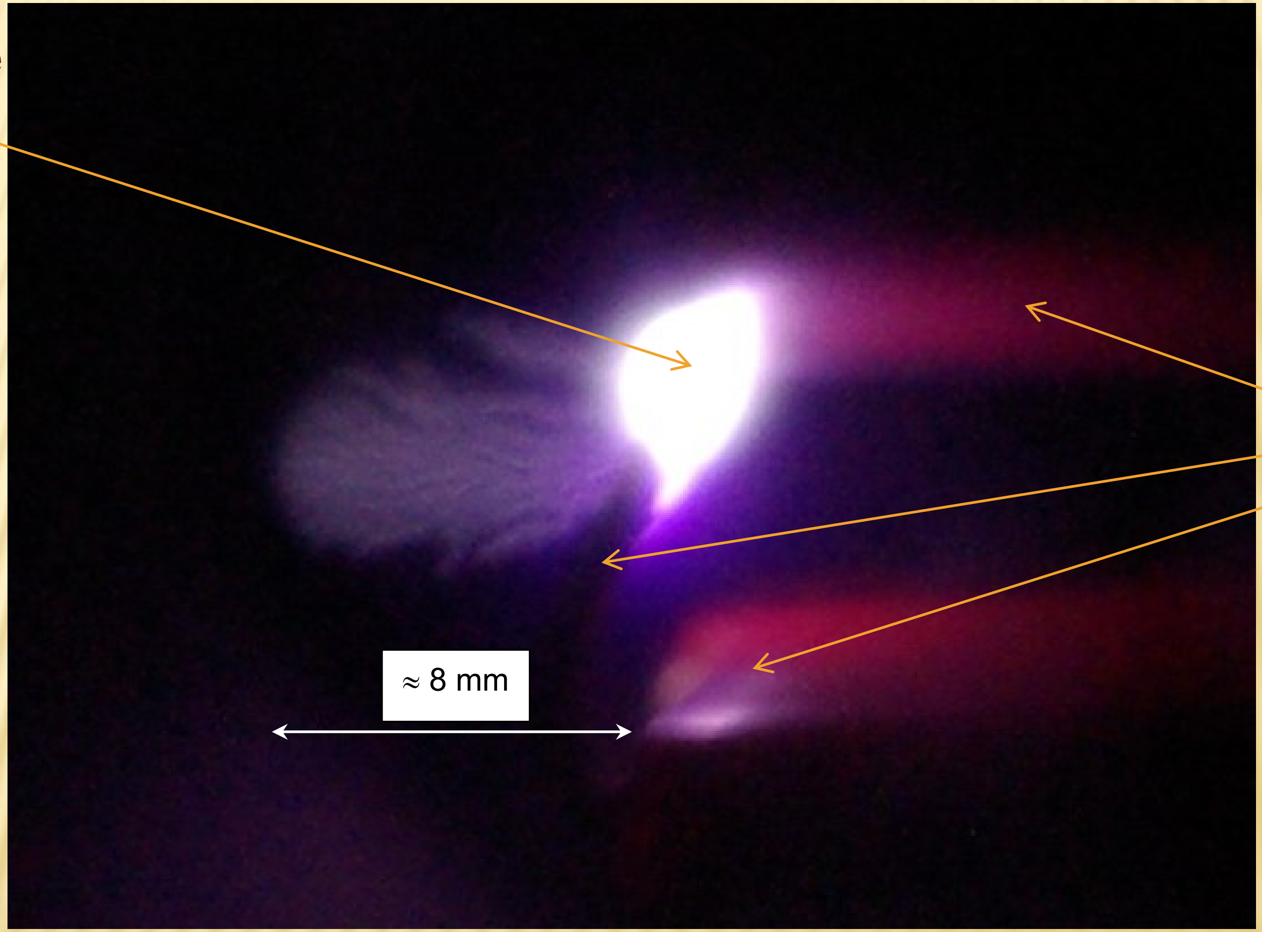
Focusing after additional mirror



Experimental setup



Discharge in Argon, pressure 0.3 atm.



Velocity of discharge propagation more than 10^5 cm/s

Experiments proof:

- High power of THz radiation
- High quality of THz beam, enough for good focusing
- Reality of further plasma physics experiments with THz radiation

Multicharged ion source based on 1 THz radiation

Cut off density $N=10^{16}$ cm^{-3}

If confinement parameter $N\tau = 10^{10}$ cm^{-3} s

↓

Confinement time $\tau \sim 10^{-6}$ s

Plasma confinement

If plasma confinement is connected with just plasma expansion in vacuum

Ion sound velocity:

$$V_s = 10^6 \sqrt{z \frac{T_e}{\mu}} \sim 10^6 \text{ см/s.}$$

Plasma dimension ~ 1 cm

Magnetization of plasma

$\omega_H >> \nu$

$B >> 10^{-2}$ Tesla

1D plasma expansion

ECR condition – about 30 Tesla

Absorption of THz radiation by plasma

- ~~ECR condition – 30 Tesla~~
- Collisional THz radiation absorption
- Hybrid resonances
- Plasma resonance

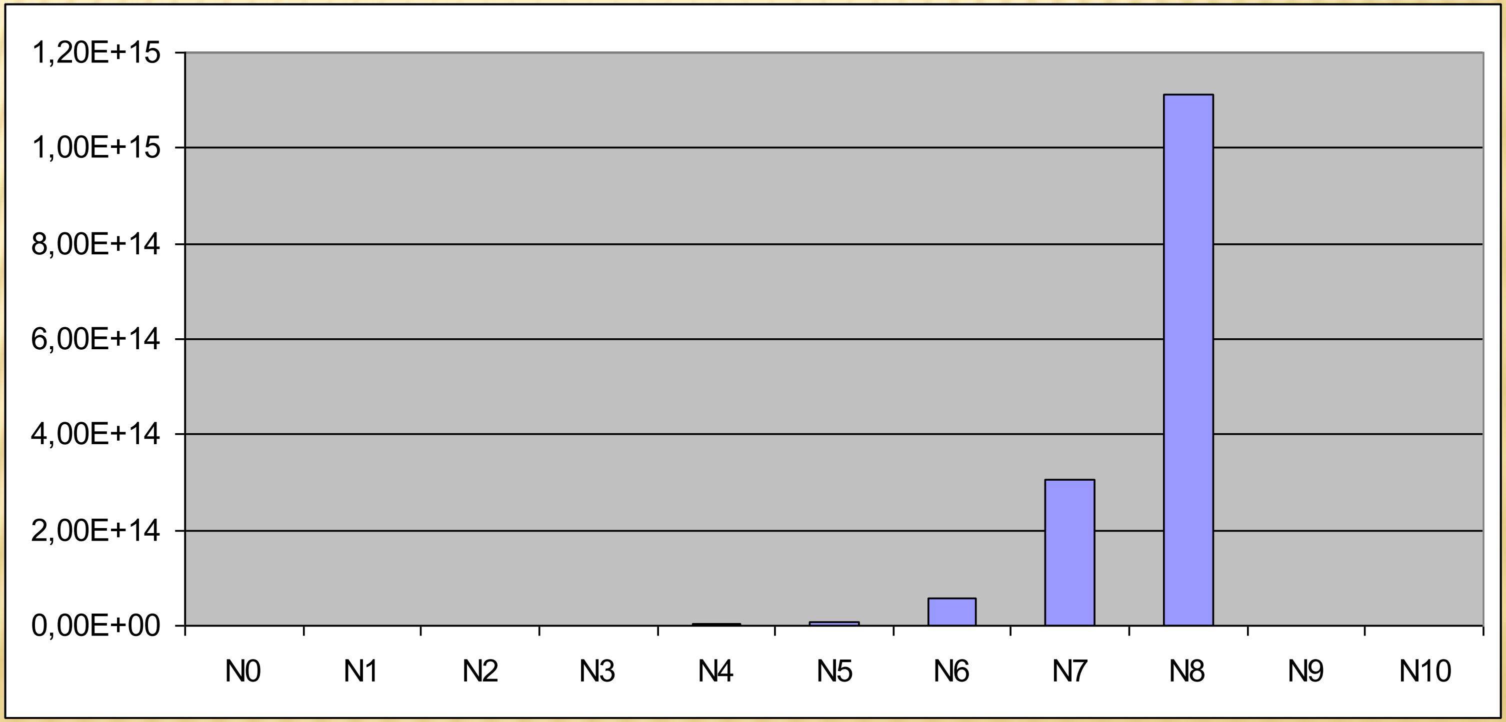
Ion temperature

Collisional heating: $T_i \sim \nu_{transport} \cdot \tau_{ion} \sim N\, \tau_{ion}$

If heating is only by collisions, one can regulate ion temperature.

Simulation for:

- Neon
- 300 kW/cm^2
- 30 cm mirror trap



Conclusion

- THz radiation is reality by now
- THz radiation looks rather promising for formation of pulsed plasma with multicharged ions.
- We are going to continue the experiments

Thanks to organizing committee
Thank you for attention
Sorry for talking not only about ECR