Pyroelectric Generator:

Acceleration of Electron & Ion Beams, X-Ray & Neutrons Production

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S. Petersburg, XL Winter School, February 2006

Content

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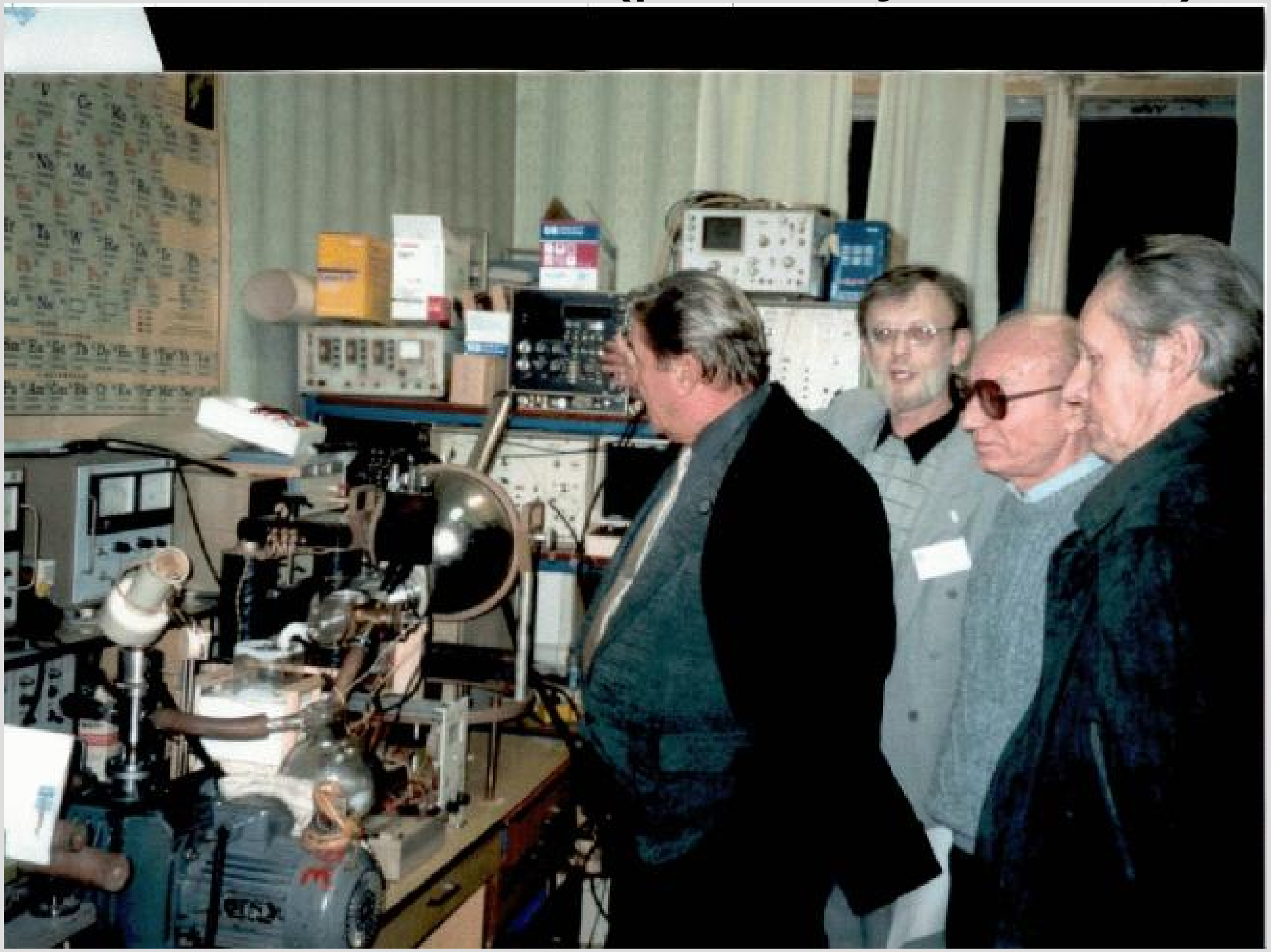
Short history

Pyroelectric Effect in Ancient Greece
Research of Kurchatov et al
Soviet physicists research in 70s – 80s
X-ray generation by Brownridge, Nature 1992
Electron beam observation 1999
Ion beam observation 2001
Neutron emission, Nature April 2005

What about us?

In 2001, we first outside of the USA observed pyroelectric X-rays (as to our knowledge) **V. I. Nagaychenko, V. M. Sanin, A. M. Yegorov, A. V. Shchagin. Spectra of pyroelectric X-ray generator. E-preprint physics/0309049 at http://www.arxiv.org/ftp/physics/papers/0309/0309049.pdf , September 10, 2003, 5 p.**

First Experiments with Pyroelectric Generator, Kharkov, 2001 (photo by X. Artru)



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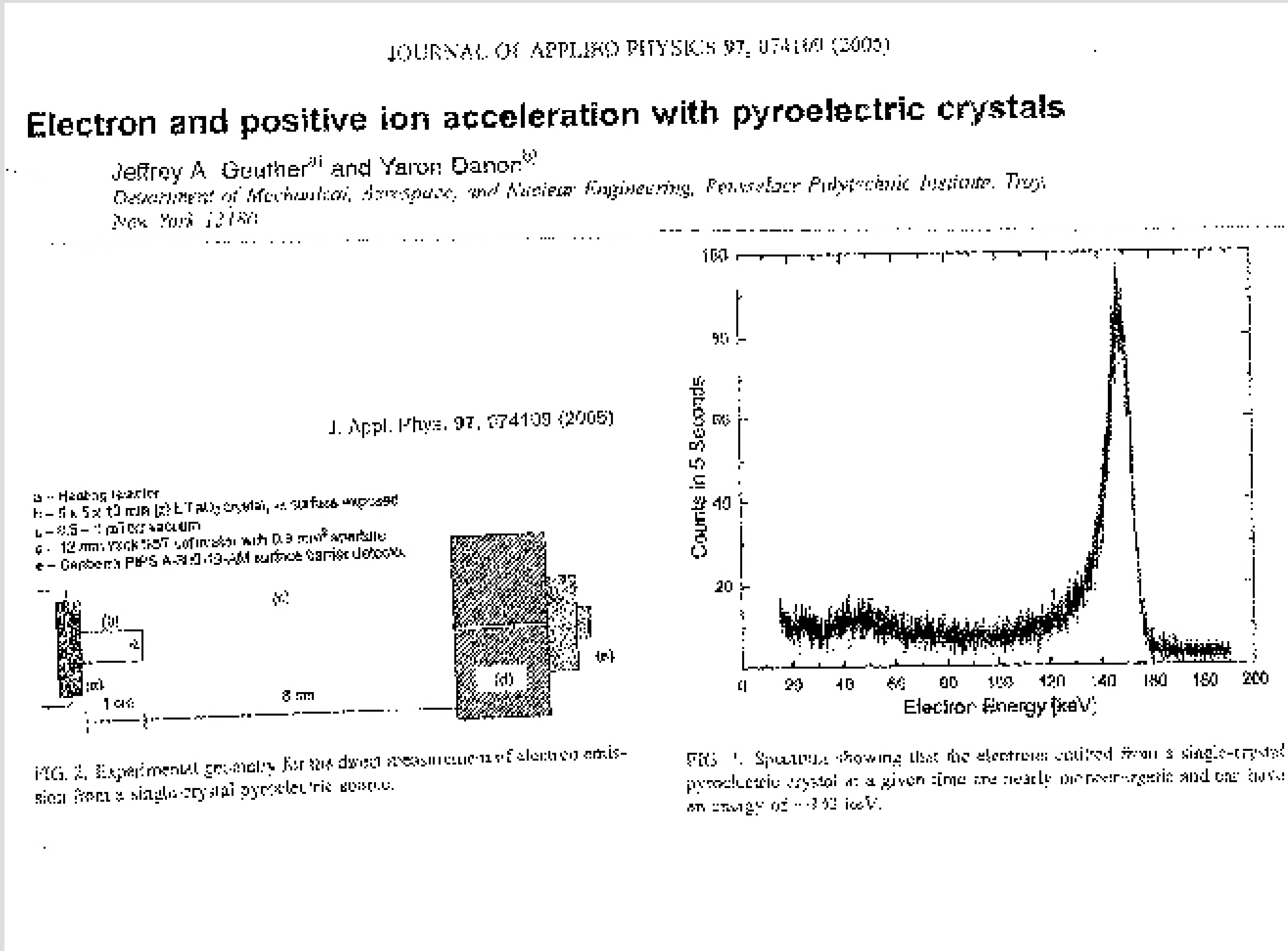
Experimental Observation of Accelerated Electron Beam Due to Pyroelectric Crystal, 2005



JOURNAL OF APPLIED PHYSICS 97, 074109 (2005)

Electron and positive ion acceleration with pyroelectric crystals

Jeffrey A. Geuther[a)] and Yaron Danon[b)]
Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, New York 12180

J. Appl. Phys. 97, 074109 (2005)

FIG. 2. Experimental geometry for the direct measurement of electron emission from a single-crystal pyroelectric source.

FIG. [illegible]. Spectrum showing that the electrons emitted from a single-crystal pyroelectric crystal at a given time are nearly monoenergetic and can have an energy of ~[illegible] keV.

Experimental Observation of Focusing of Accelerated Electron Beam

This preprint is now in press at: http://novapublishers.com/catalog/product_info.php?products_id=2176

Revised Draft 1 May 2004

Electron and Positive Ion Beams and X-rays Produced by Heated and Cooled Pyroelectric Crystals such as $LiNbO_3$ and $LiTaO_3$ in Dilute Gases: Phenomenology and Applications

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Department of Physics, Applied Physics and Astronomy, State University of New York at Binghamton, P.O. Box 6000, Binghamton, New York 13902-6000, e-mail jdbjdb@binghamton.edu

Stephen M. Shafroth
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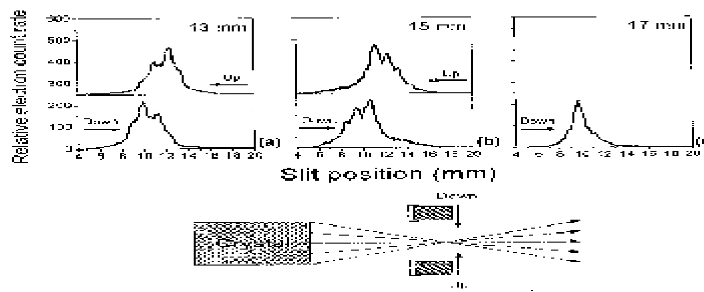

Fig. 29 Results of beam scan to determine if the beam was stable over time and if there was structure in the beam. An arrow indicates the direction of each scan.

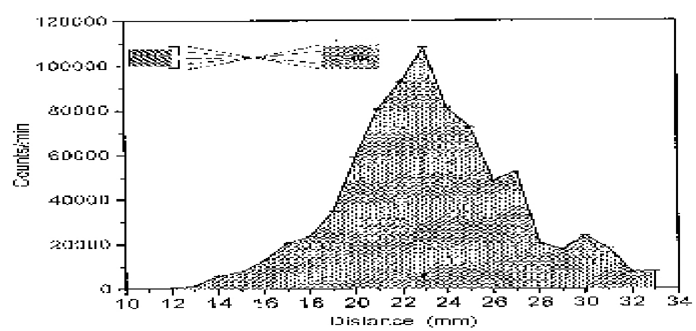

Fig. 30 Results of a beam scan when the detector is moved along a line that runs through the center of the crystal parallel the z-axis. This was a 4mm in diameter and 10 mm long $LiNbO_3$ crystal.

Experimental Observation of Accelerated Ion Beam Due to Pyroelectric Crystal, 2005

JOURNAL OF APPLIED PHYSICS 97, 074109 (2005)

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(Received 29 November 2004; accepted 9 February 2005; published online 23 March 2005)

J. Appl. Phys. 97, 074109 (2005)

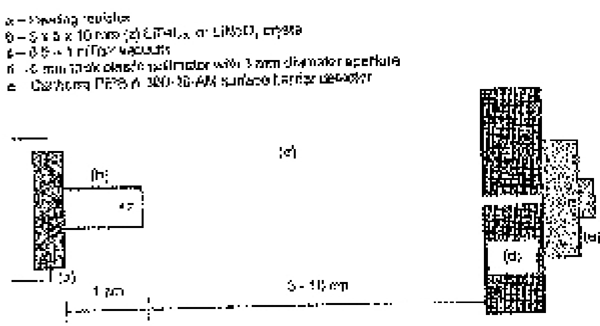


FIG. 5. Experimental geometry for the detection of positive ions accelerated by the potential from a pyroelectric crystal.

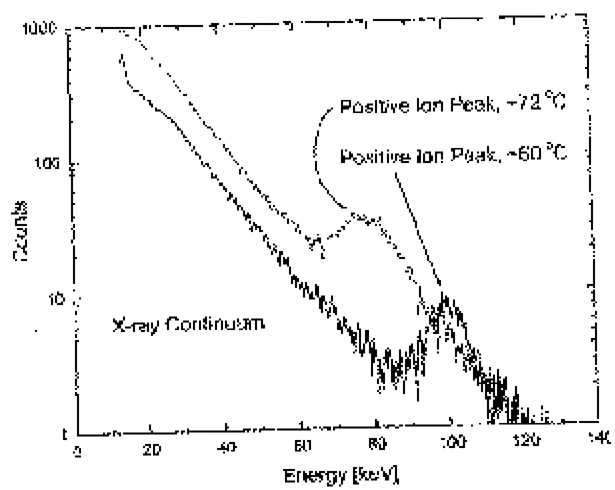


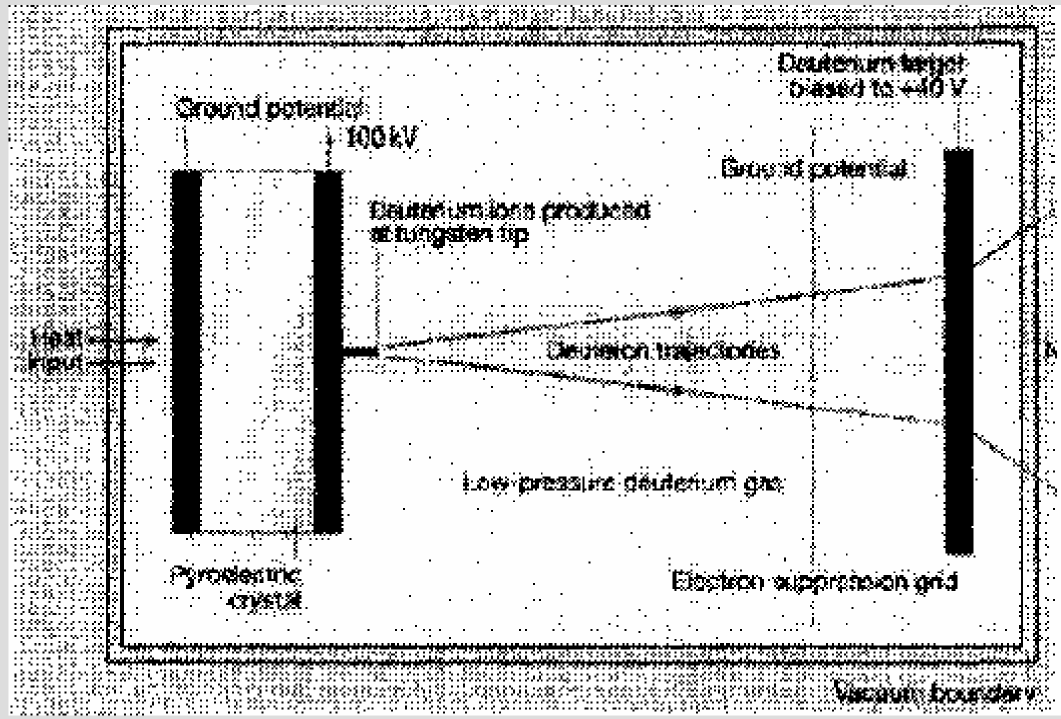
FIG. 6. Positive-ion spectra for a [illegible] source during cooling. The positive-ion peak changes in energy as the crystal cools.

Experimental Observation of Nuclear Fusion Driven by a Pyroelectric Crystal, 2005

Fusion seen in table-top experiment

27 April 2005

Physicists in the US have generated nuclear fusion in a simple, table-top device operating at room temperature. The device, built by Brian Naranjo, Jim Gimzewski and Seth Putterman at the University of California at Los Angeles (UCLA), causes two deuterium nuclei to collide with each other and generate alpha particles, neutrons and energy (*Nature* 434 1115). The device could have applications as a portable neutron generator or in the propulsion systems for miniature spacecraft, but will not be useful as an energy source because it consumes more energy than it produces.



D. Naranjo et al, Nature, 434 1115 (2005)

Experimental Observation of Nuclear Fusion Driven by a Pyroelectric Crystal, 2005

letters to nature

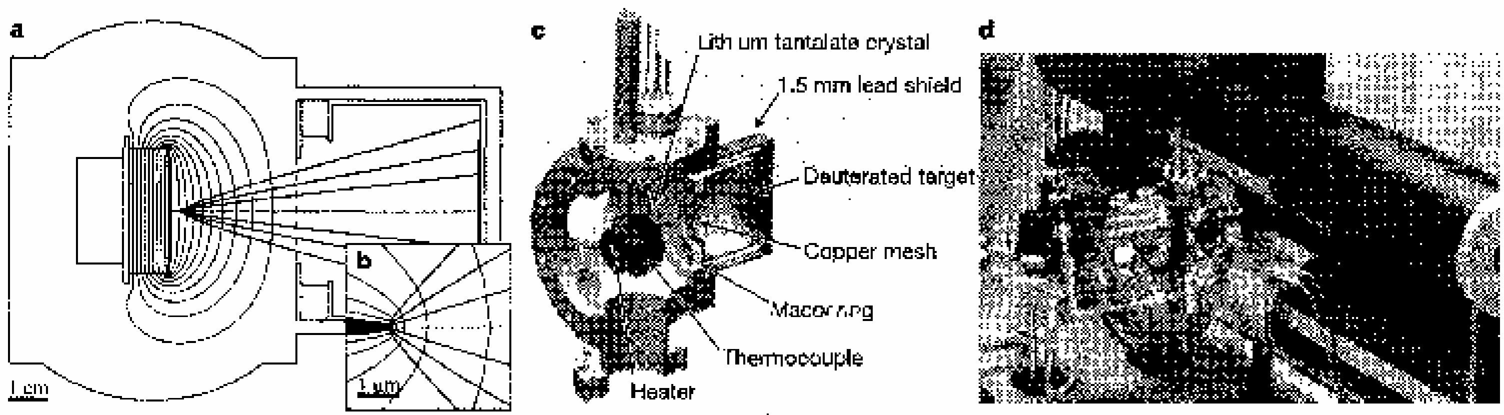


Figure 1 Experiment geometry. **a**, Calculated equipotentials and D^+ trajectories for a crystal charged to 100 kV; calculations were performed using finite-element methods. The grounded copper mesh (85% open area, 19.8-µm wire; vertical dashed line) shields the Faraday cup (right). The cup and target are connected to a Keithley 6485 picoammeter and biased to +40 V to collect secondary electrons and help prevent avalanche discharges. **b**, Same trajectories shown near the tip. Using a shorter tip reduces the beam's angular spread. **c**, Vacuum chamber cut-away view. D_2 pressure was set using a leak valve and monitored with a D_2 compensated Pirani gauge. The target was a molybdenum disc coated with ErD_2. **d**, Arrangement of neutron and X-ray detectors (Amptek XR-100T-CdTe). To better resolve the bremsstrahlung endpoint, a 2.5-cm aluminium filter (not shown) was placed between the X-ray detector and the viewport. The vacuum chamber's thick stainless steel walls and lead sheet shielded the neutron detector from X-rays.

D. Naranjo et al, Nature, 434 1115 (2005)

Experimental Observation of Nuclear Fusion Driven by a Pyroelectric Crystal, 2005

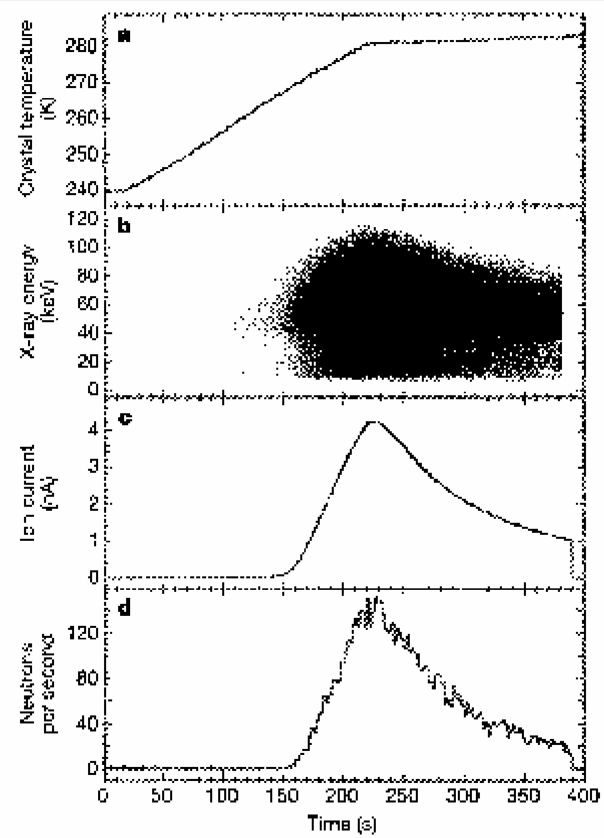
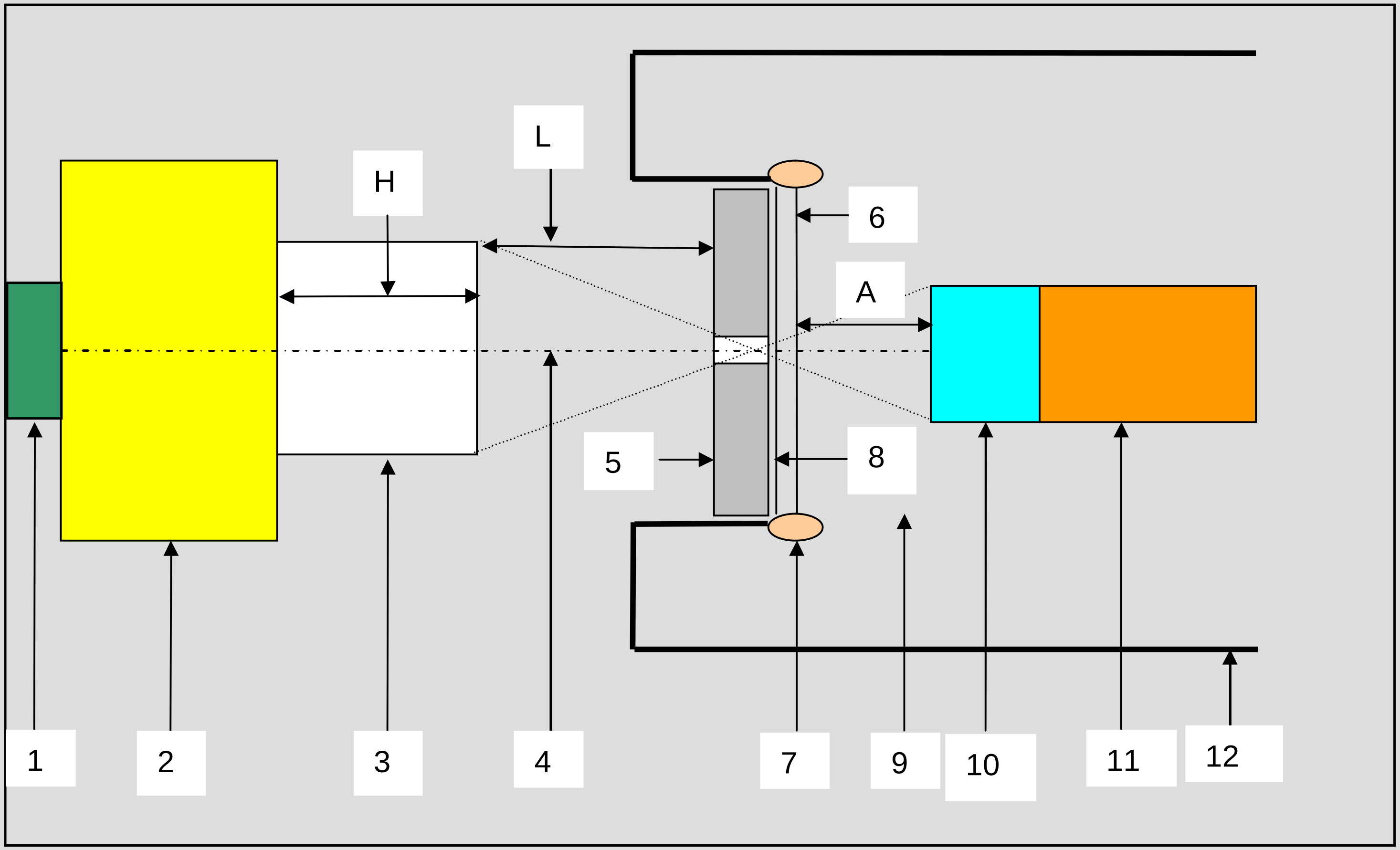


Figure 2 Data from a single run (see also Supplementary Movie 1). **a**, Crystal temperature. The heating rate was 12.4 K min^{-1}, corresponding to a pyroelectric current of 22 nA and a heating power of 2 W. **b**, X-rays detected. **c**, Faraday cup current. **d**, Neutrons detected.

D. Naranjo et al, Nature, 434 1115 (2005)

Experiments with Pyroelectric Generator, Kharkov, 2005



Scheme of the experimental setup with pyroelectric crystal LiNbO3 (3), Si(Li) X-ray detector (10), 1.0 mm lead collimator (5), 20 mkm Cu foil (8), 20 mkm Be foil (6). L=8mm.

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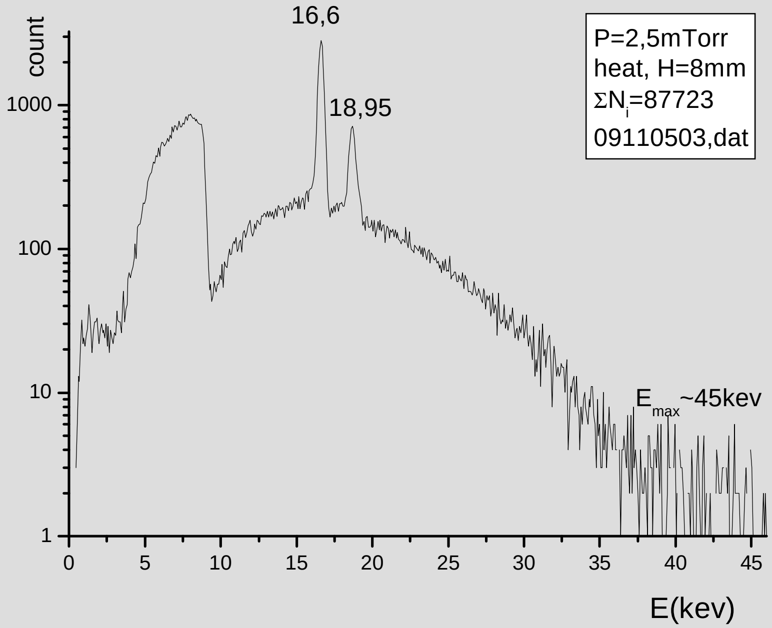
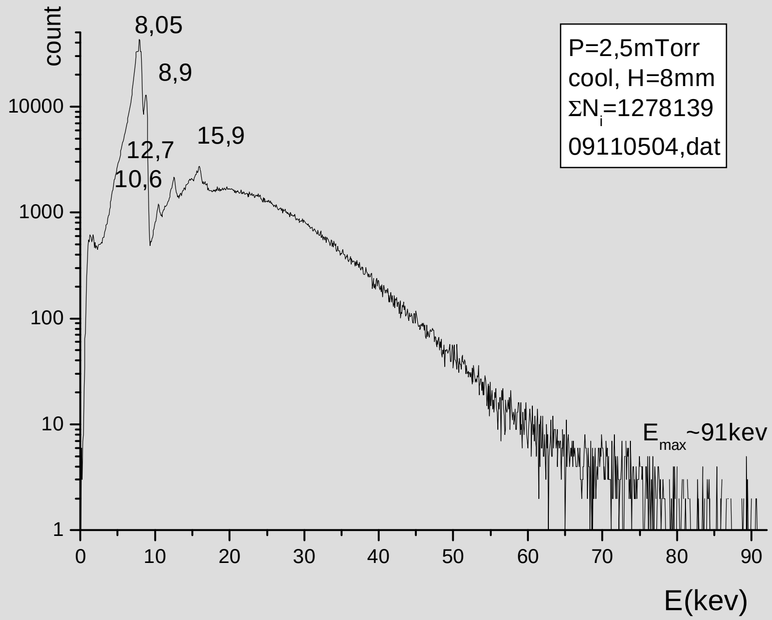
Experiments with Pyroelectric Generator, Kharkov, 2005

Heating



Cooling



X-ray spectra at heating and cooling -20 – +110 degree. Crystal **LiNbO3, height H=8 мм pressure P=2.5 mTorr**

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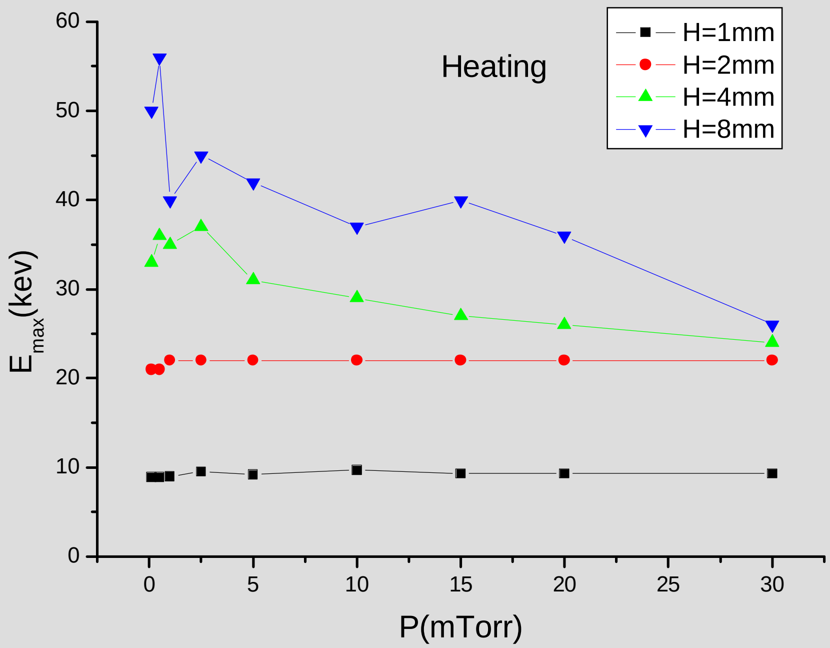
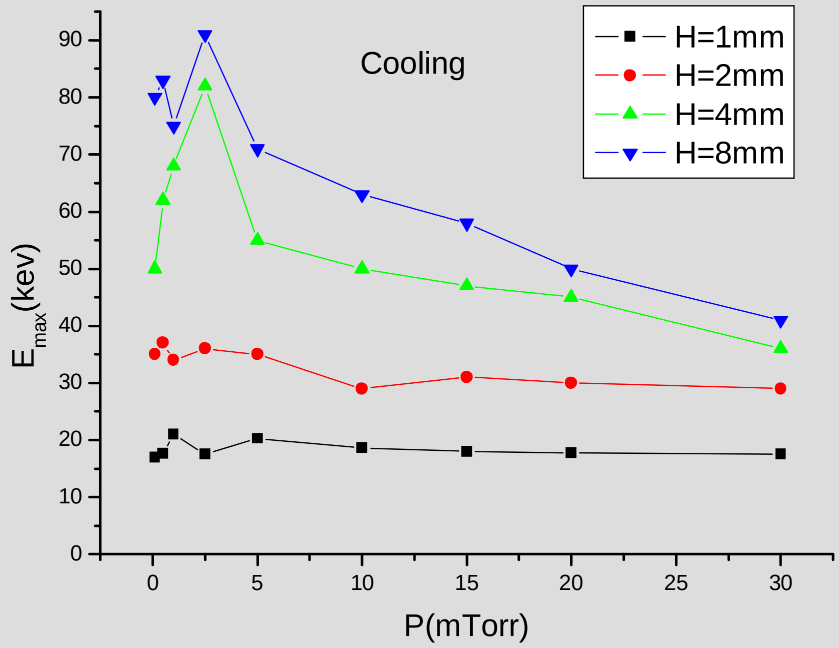
Experiments with Pyroelectric Generator, Kharkov, 2005

Heating



Cooling



Maximum energy in X-ray spectra as a function of pressure at different crystal height

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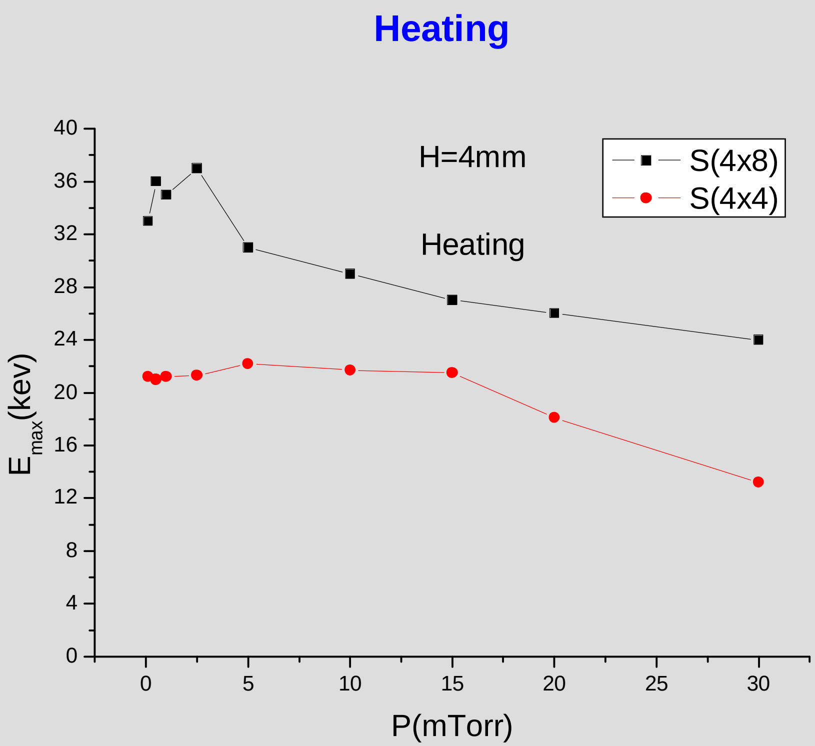

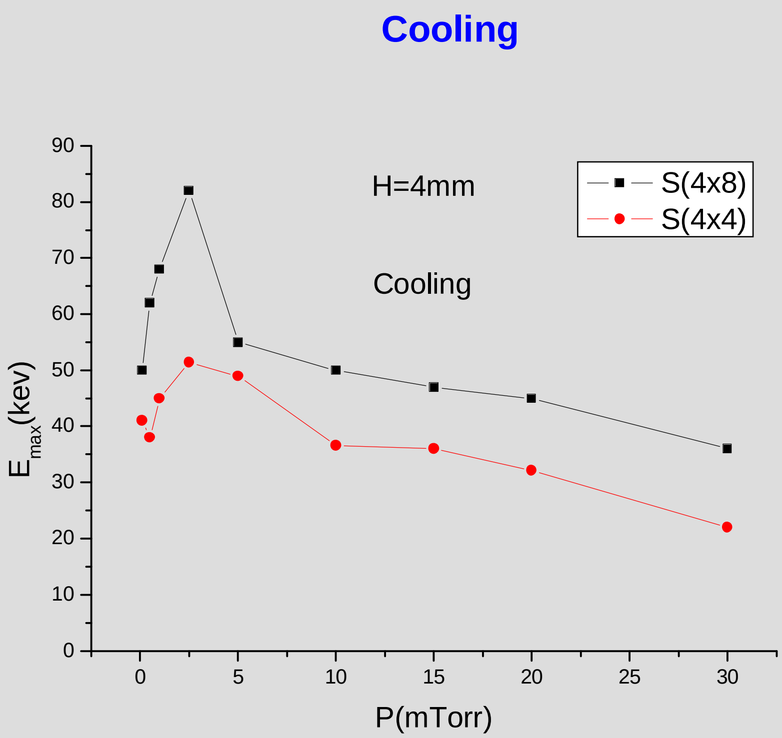

Maximum energy in X-ray spectra as a function of pressure at different crystal square

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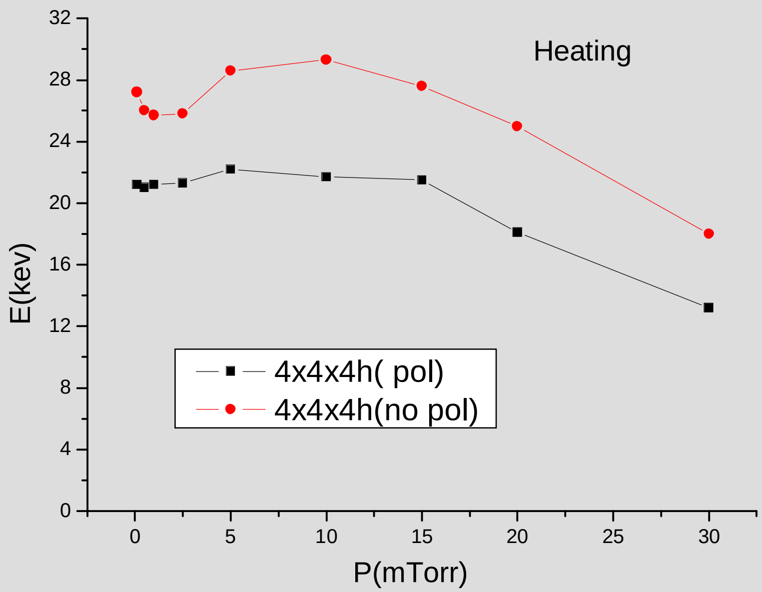
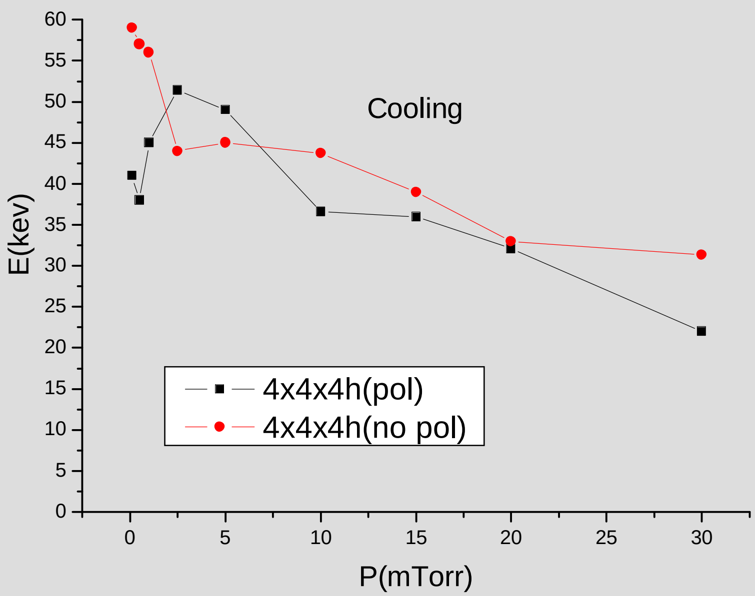
Experiments with Pyroelectric Generator, Kharkov, 2005

Heating



Cooling



Maximum energy in X-ray spectra as a function of pressure for non-polished and polished crystal

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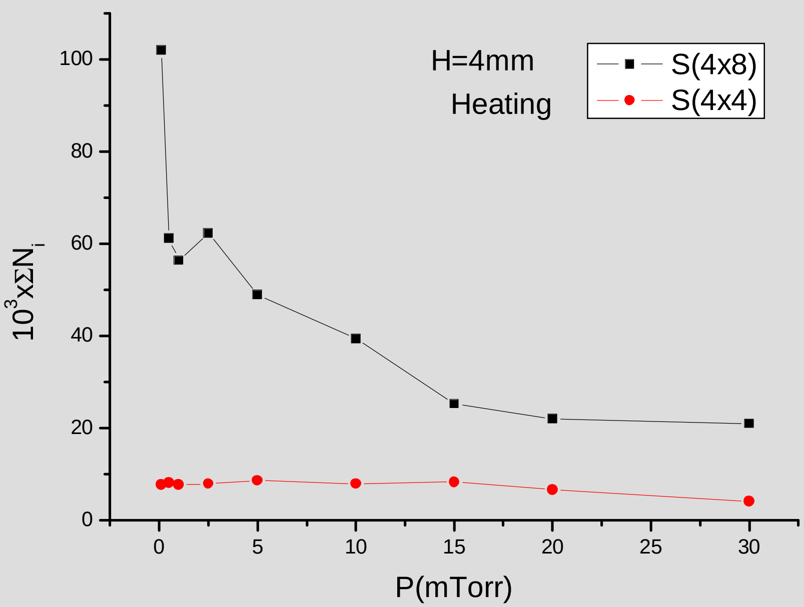
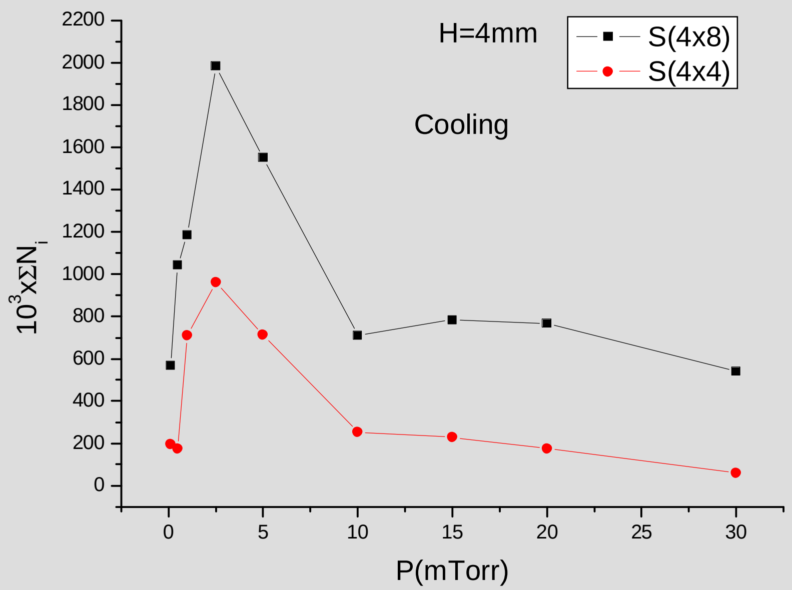
Experiments with Pyroelectric Generator, Kharkov, 2005

Heating



Cooling



Total number of X-ray quanta as a function of pressure for different crystal thicknesses

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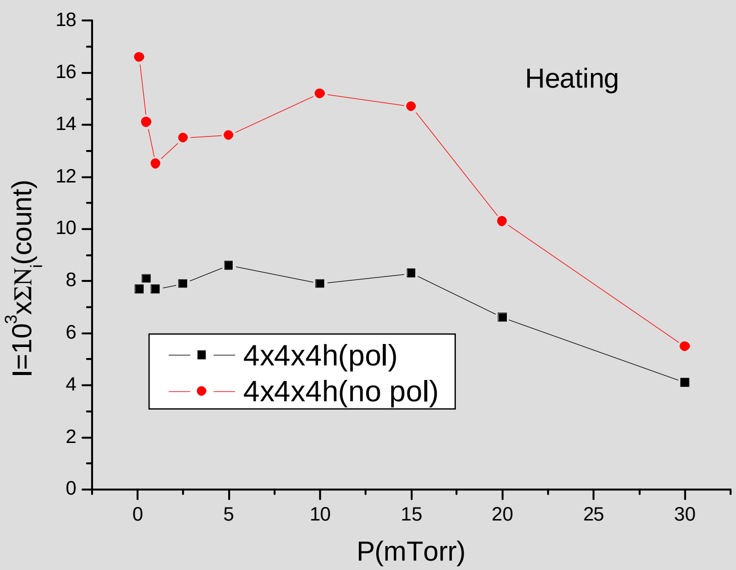
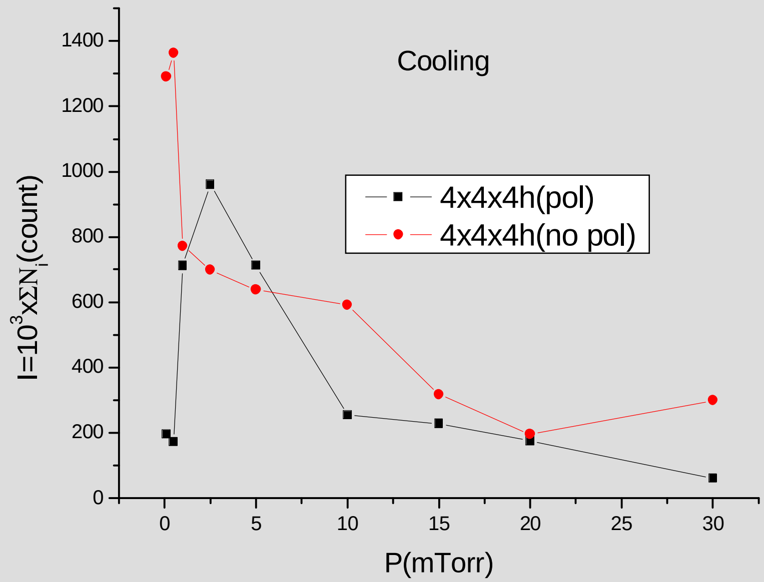
Experiments with Pyroelectric Generator, Kharkov, 2005

Heating



Cooling



Total number of X-ray quanta as a function of pressure for non-polished and polished crystal

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Images of Focused Electron Beam at ZnS Screen, Kharkov, 2005

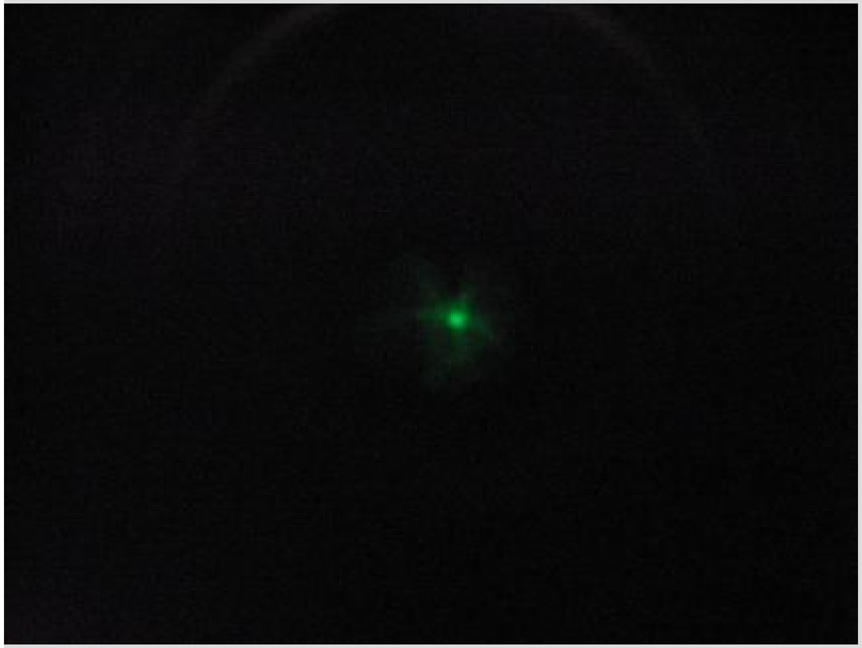

Fig. 24

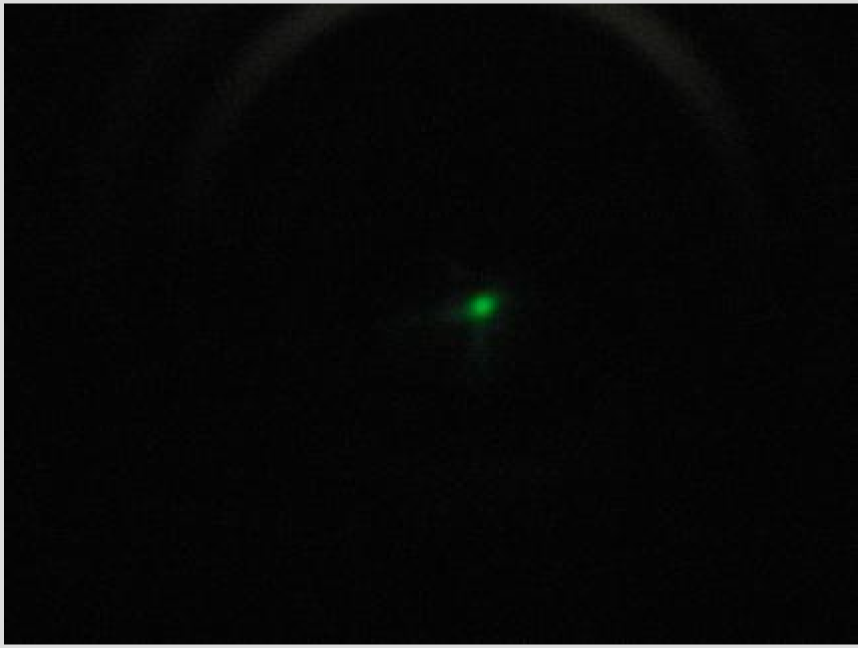

Fig. 33

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What We are Going to Do?

1. To create the experimental setup
2. To study properties of the electron beam, including the beam focusing
3. To study generation of X-rays
4. To study properties of the ion beam

Later, may be

5. Numerical simulation of the pyroelectric generator operation
6. To research generation of neutron emission.

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I Would Invite Everyone

for Experimental Demonstration

of the **Pyroelectric Generator**

Operation at KIPT

Room 207, Bld. 5, New Site,

on January 20, 2006

starting from 16:00

Thanks

for Your Attention！