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PIEZOELECTRIC TRANSFORMER AIDED X-RAY GENERATION IN VACUUM

A. V. Shchagin,[1, 2, 3] V. S. Miroshnik,[2] V. I. Volkov,[2] A. S. Kubankin,[1, 4] and O. O. Ivashchuk[1]

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The results of an experimental study of x-ray generation aided by a ceramic piezoelectric transformer placed in vacuum are presented. X-rays were emitted with the piezoelectric transformer tuned to resonance at about 20 kHz. A characteristic emission peak of a titanium target at energy of 4.5 keV against the Bremsstrahlung background was observed in the measured x-ray spectra. The maximum energy of the x-ray Bremsstrahlung reaches 12 keV. This means that the electrons are accelerated in vacuum in the field of the piezoelectric transformer to at least 12 keV.

Key words: ceramic piezoelectric transformer, x-ray generation.

New small electron accelerators and x-ray generators, generating x-rays with energy up to 100 keV, based on the pyroelectric effect, a pyroelectric crystal [1] or pyroelectric ceramic [2, 3], and the triboelectric effect [4, 5] have been proposed in recent years. Recent experiments were performed on x-ray generation aided by a crystalline piezoelectric transformer placed in vacuum [6] or air [7]. Generation of up to 127 keV x-rays was reported in [6], and it was shown in [7] that the voltage at the output of the piezoelectric transformer does not exceed 2 kV.

To establish the possibility of using a piezoelectric transformer to obtain radiation we began experiments on x-ray generation aided by a ceramic piezoelectric transformer placed in vacuum.

EXPERIMENT

The experimental arrangement assembled in a vacuum chamber with regulatable pressure is displayed in Fig. 1. A PT-R1 ceramic, single layer, piezoelectric transformer with dimensions $80 \times 10 \times 3$ mm was used to generate high voltage. A target comprised of 20 ìm thick titanium foil was placed 30 mm from the high-voltage electrode of a piezoelectric transformer, and an x-ray detector was placed 6 mm behind the target.

A 100 μm thick beryllium entry window of the detector opened into the vacuum chamber. A tungsten filament was installed near the target. The x-ray spectrum was measured at residual gas (air) pressure in the chamber 3 mTorr.

The x-ray spectrometer consisted of an XR-100T CdTe-detector and a PX4 (Amptek) digital processor connected with a computer. The pulse formation time (peaking time) in the spectrometer was equal to 4.0 μsec. The energy

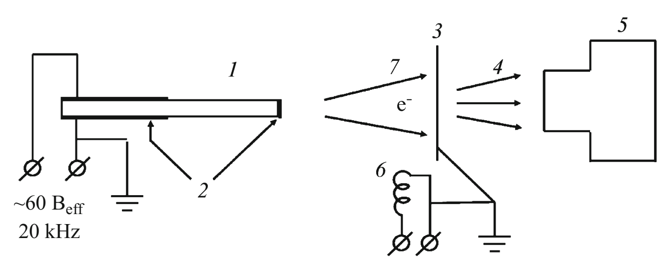
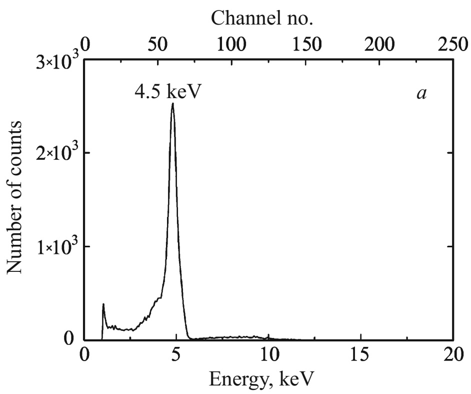


Fig. 1. Experimental arrangement: *1*) PT-R1 piezoelectric transformer; *2*) silver electrodes; *3*) target comprised of titanium foil; *4*) x-ray radiation; *5*) x-ray detector; *6*) tungsten filament; *7*) electrons.

[1] International Scientific and Educational Laboratory of Radiation Physics, Belgorod State National Research University, Belgorod, Russia.
[2] National Scientific Center – Kharkov Institute of Physics and Technology, Kharkov, Ukraine.
[3] E-mail: shchagin@kipt.kharkov.ua.
[4] E-mail: kubankin@bsu.edu.ru.



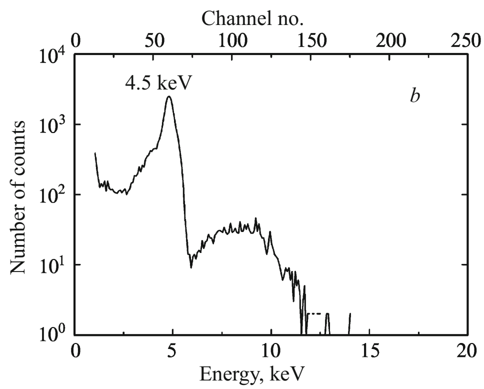


Fig. 2. X-ray spectrum in linear (*a*) and logarithmic (*b*) scales.

calibration of the spectrometer was performed with the aid of the radioactive sources ^{55}Fe and ^{241}Am. The energy resolution of the spectrometer (FWHM) was equal to about 400 eV.

A sinusoidal signal with effective voltage 60 V was fed from a GZ-123 generator into a piezoelectric transformer. A signal was fed into the low voltage silver electrodes of the piezoelectric transformer. The signal frequency, equal to about 20 kHz, was picked so as to excite the first resonance harmonic of the piezoelectric transformer and to obtain x-rays. In this case an alternating high voltage appears on the high-voltage silver electrode of the piezoelectric transformer.

The piezoelectric transformer heats up during operation. Ordinarily, it is located in the atmosphere and is cooled by ambient air. In vacuum there is no air cooling. For this reason in our experiment the piezoelectric transformer operated in vacuum for about 5 min, after which it was switched off and cooled. During heating the resonance frequency of the piezoelectric transformer decreased and the frequency of the feed signal had to be fine-tuned.

Once the filament is connected, a vacuum diode forms between the high-voltage electrode of the piezoelectric transformer and ground. For this reason a pulsing sinusoidal voltage, which periodically changes from 0 to twice the negative-polarity amplitude, is formed on the high-voltage electrode. For negative polarity of the irregularities of the high-voltage electrode of the piezoelectric transformer field-emission of electrons occurs, and these electrons are accelerated in a direction of the grounded target. The accelerated electrons enter the target and form characteristic and Bremsstrahlung x-rays, which are detected by an x-ray spectrometer. The x-ray spectrum measured in 5 min is displayed in Fig. 2 in linear (*a*) and logarithmic (*b*) scales.

EXPERIMENTAL RESULTS

It is evident in Fig. 2*a* that the spectrum contains a distinct peak due to the characteristic 4.5 keV K-radiation of titanium against the background due to Bremsstrahlung. The Bremsstrahlung has a jump in intensity at the 5.0 keV K-absorption edge of titanium, since the absorption of x-rays in titanium foil increases sharply at energy above the K-edge. It is evident in Fig. 2 that the maximum energy of the Bremsstrahlung reaches about 12 keV. This means that the energy of the accelerated electrons is at least 12 keV, and the maximum negative potential on the high-voltage electrode of the piezoelectric transformer is at least 12 kV.

CONCLUSIONS

Our experiments have shown that the electron acceleration and x-ray generation occur with the aid of a ceramic piezoelectric transformer placed in vacuum.

The electron energy and peak Bremsstrahlung energy can be increased by using a piezoelectric transformer with a higher coefficient of transformation or a Cockroft–Walton high-voltage multiplier.

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