

# Development of experimental set-up for the investigation of photoelectric response of the pyroelectric crystal to short pulses of the Hg(Xe) lamp

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The experimental set-up was developed for the measurement of the photoelectric response of a LiTaO<sub>3</sub> crystal under illumination of a Hg(Xe) lamp. The set-up includes a vacuum chamber with sample stage and the Hg(Xe) lamp with a light shutter and optical feedthrough to chamber. The LiTaO<sub>3</sub> crystal was simultaneously heated by a resistive heating element and irradiated with the Hg(Xe) lamp with a pulse duration/delay time of 10/10 sec, respectively. To increase radiation absorption, a radiation-reflecting molybdenum layer was deposited on the side opposite the irradiated surface of the crystal. Fast photoelectric response of the LiTaO<sub>3</sub> crystal and the increase of the photocurrent about five times was found for coated sample in comparison with uncoated one.

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## 1. Introduction

Pyroelectric materials have attracted attention due to their unique properties and application possibilities, for instance, as fast detectors from gamma to infrared radiation, as devices for generating x-rays and neutron flux, as well as for harvesting environmental energy and converting it into electricity, motion and more [1,2].

Formation of electric charges on the polar surfaces of pyroelectrics directly depends on changes in the temperature gradient created in the heating-cooling cycle. Subject to certain limitations, the greater the gradient, the stronger the electric charge and electrostatic field obtained on polar surfaces. The temperature gradient can be generated either by direct heat transfer, or by external electric field and electromagnetic radiation, or by combination of both. The laser or lamp can be used for fast heating of the surface of pyroelectric crystal [3].

An important parameter of pyroelectric materials is a response time to disturbances from external sources that cause changes in the temperature gradient. With a stepwise change in the intensity of the heat flux acting on the crystal, for instance, as in the case of conventional heating-cooling cycle by a resistive heating element, the increase in the amplitude of the voltage response and the achievement of its maximum value occurs relatively slowly with a delay of the order of ms [4]. One of the interesting questions is the characteristics of the photoelectric response of the LiTaO<sub>3</sub> and LiNbO<sub>3</sub> crystals to a short radiation pulse in the wavelength range of 200-

2500 nm. It has previously been shown that the photoelectric response to UV radiation can be very fast for LiTaO<sub>3</sub> and LiNbO<sub>3</sub>, i.e. in ps and ns ranges [3,5]. Ultraviolet photodetectors are important for application in automatization, communication technology, biological research, military equipment etc.

An effective method to improve the response of the pyroelectric crystal to optical disturbances is to place a radiation reflector on the side opposite the irradiated surface of the crystal [6]. The optical properties of the crystal are characterized by the fact that part of the radiation can pass through the crystal, i.e. this part of the energy is not absorbed and does not affect the temperature gradient. The reflector on the surface of the crystal provides backscattering and significantly increases the energy absorption in the crystal body affecting the temperature gradient.

The main aim of the study was the development and testing of experimental set-up for the measurement of the pyroelectric crystal photoelectric response to the short pulses of the Hg(Xe) lamp.

## 2. Experimental

Congruent LiTaO<sub>3</sub> crystals (10x10x1 mm) were purchased from BIOTAIN Crystal Co. Ltd. A thin Mo layer with a thickness of 400 nm was deposited on +Z side of the LiTaO<sub>3</sub> crystal using magnetron sputtering. The Mo layer acts as a radiation reflective layer.

An experimental set-up was developed to collect data (Figs. 1-3). The set-up includes a sample stage (Fig. 1) and optical system (Fig. 2) assembled in a vacuum chamber (Fig. 3). The sample stage includes ceramic (silicon nitride) resistive heating element (Bach RC GmbH, 7E-10000-14-17) to heat up the crystal and Pt100 type temperature sensor (Bach RC GmbH) to measure the temperature. Molybdenum mesh with open area of 67% (GoodFellow GmbH, MO00-MS-000112) was used to pass the lamp illumination to the surface of the sample and copper foil to collect electron current. The optical system consists of the 350 W Hg(Xe) lamp L2483 (Hamamatsu) with condensing optics, cooling system and electromechanical shutter LSZ166 (Quantum Design Inc.). The Hg(Xe) lamp pulse and delay durations were 10 sec and the lamp power was 350 W during measurements. The -Z side of LiTaO<sub>3</sub> crystal was under illumination. The electron current generated by crystal was collected using Cu-foil and Mo-mesh. Electrical measurement setup consists of data acquisition board NI-USB6366 (National Instruments), measurement cables and external 1 M $\Omega$  shunt. Currents were measured as a voltage drop over the shunt resistor connected between the top and bottom electrodes [7].

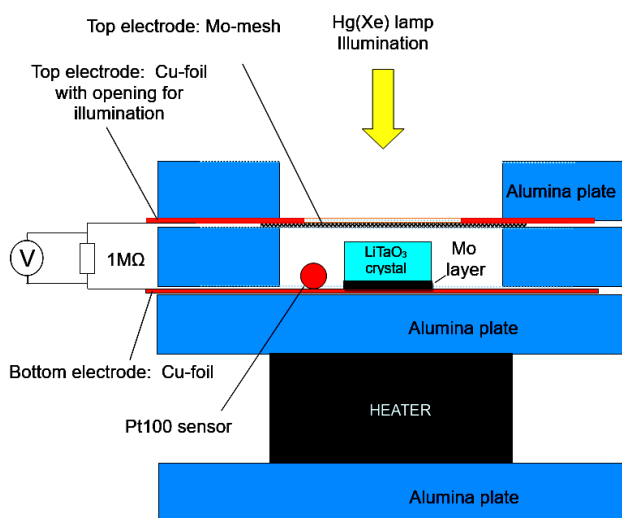


Fig. 1. Probe stage (color online)

Vacuum pressure in chamber was  $10^{-5}$  mbar during the measurement. The distance between the sample and Mo-mesh was 0.5 mm.

The purpose of this set-up was to use Mo-mesh electrode enabling light to pass to the crystal simultaneously with the collection of electrons generated by pyroelectric crystal. Solid electrode is another option to collect electrons [8], however in this case the incident light direction cannot be normal to the pyroelectric crystal surface, leading to a loss of incident power due to reflection.

### 3. Results and discussion

In the present study, two energy sources were used, namely the resistive heating element and the Hg(Xe) lamp. Therefore, the total measured current consists mainly of two components, i.e. ones caused by the temperature gradients generated by the resistive heating element and by the Hg(Xe) lamp illumination. The aim of the study was investigation of the LiTaO<sub>3</sub> crystal photoelectric response to short pulses of the Hg(Xe) lamp, therefore the resistive heating element was used only to heat the samples up to working temperature and to stabilize sample stage at this temperature. The working temperature was about 100 °C. The stabilized temperature was monitored by temperature gradient value, which was between 0.03-0.04 °C/sec, i.e. with slight increase in temperature during the illumination tests. Therefore, the influence of resistive heating element on the total electron current was minimized.

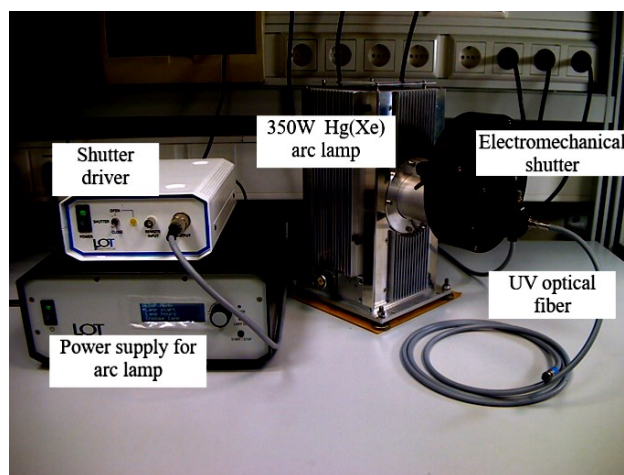


Fig. 2. Optical system (color online)

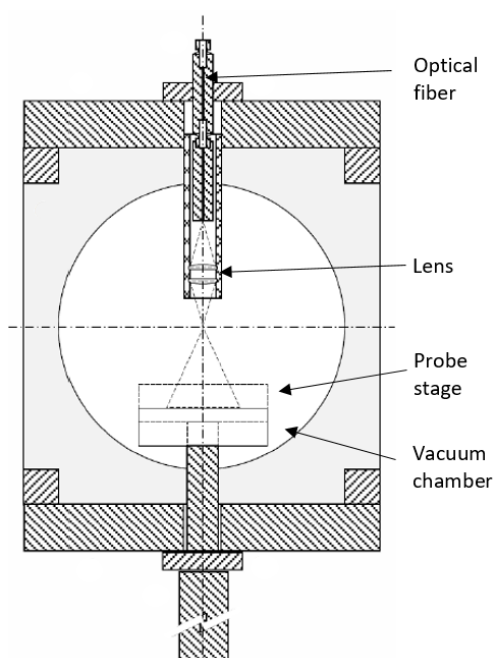


Fig. 3. Installation in the vacuum chamber

The results of the measurements are shown in Fig. 4. The current generated during the illumination was recorded, the current value with illumination switched ON is shown in red (pulse ON) and with illumination switched OFF in black (pulse OFF). The amplitude of the current pulse for the LiTaO<sub>3</sub> crystal with Mo layer, shown by arrows in Fig. 4, is about five times larger than that for the LiTaO<sub>3</sub> crystal without Mo layer. Sharp increase in photocurrent indicates fast photoelectric response of the LiTaO<sub>3</sub> crystal (Fig. 4b). These results indicate expected improvement of the photoelectric response of the LiTaO<sub>3</sub> crystal due to radiation reflector [6] and a good functionality of the designed experimental set-up. The shape of current pulses is permanently changed during the illumination pulse (see ellipses in Fig. 4b), indicating relaxation processes during heating/cooling cycles.

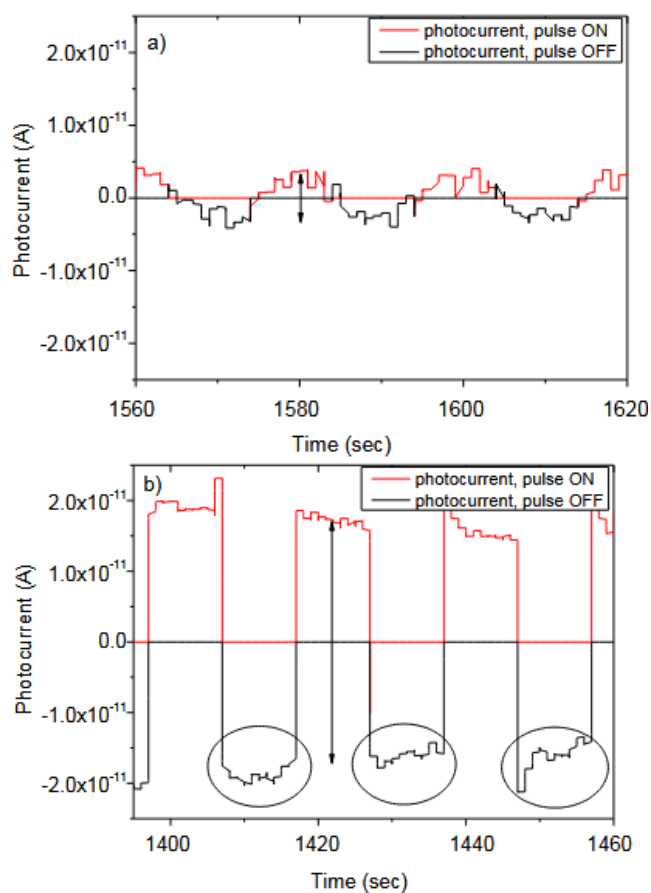


Fig. 4. Results of the current measurements during Hg(Xe) lamp illumination (a) LiTaO<sub>3</sub> sample without Mo layer and (b) LiTaO<sub>3</sub> sample with Mo layer (color online)

#### 4. Conclusions

The experimental set-up for measurement of photoelectric response of the LiTaO<sub>3</sub> crystal to short pulses of Hg(Xe) lamp was successively developed and tested. The study results showed a rapid response of the LiTaO<sub>3</sub> crystal to the illumination of the Hg(Xe) lamp. The approximately five times increase in the current pulse amplitude for the LiTaO<sub>3</sub> crystal coated with the 400 nm thick Mo layer was observed in comparison with uncoated sample. Thus, the good functionality of the experimental set-up was demonstrated.

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