UDC 53.087.51

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# LOW PHOTON COUNT IMAGING

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Under low brightness conditions the digital detector registers a small number of photons, i.e. the image contains a small number of active pixels. The paper analyzes the distribution of active and empty pixels of digital detectors under poor uniform illumination. Results of experiments on registration of uniform X-ray radiation by a digital CCD camera are presented. It is shown that registration of individual photons has a local pattern in the form of peaks varying in symmetry and size.

In the X-ray wavelength range, digital CCD cameras are used as detectors. In order to obtain a statistically reliable image, it is necessary to provide sufficient photon flux per individual pixel of the digital detector, which leads to large time and radian load on the object of study in the methods of analysis. It is proposed to consider the problem of detecting images of objects in insufficient light conditions. We will use irregularity of detector illumination as a feature of object.

Consider a digital detector of size L by H pixels under conditions of uniform illumination, with the number of photons F hitting the detector:

$$F = (LH)^x, \quad (1)$$

where x is the level of detector filling, L, H are the number of pixels in the length and height of the detector.

Consider a detector of size 2 by 2 (L=2, H=2), which detected 4 photons (x=1) at uniform illumination of the detector. Under uniform illumination, the probability of a photon hitting a pixel is equal:

$$P = \frac{1}{LH}, \quad (2)$$

Then the probability of uniformly filling the detector with photons is 9.4% (Figure 1 A). The highest probability event is 56.2% (Figure 1 B) - filling of three pixels. The probability of photons hitting two pixels is 32.8% (Figure 1 C). The probability of all photons hitting one pixel equals 1.6% (Figure 1 D).

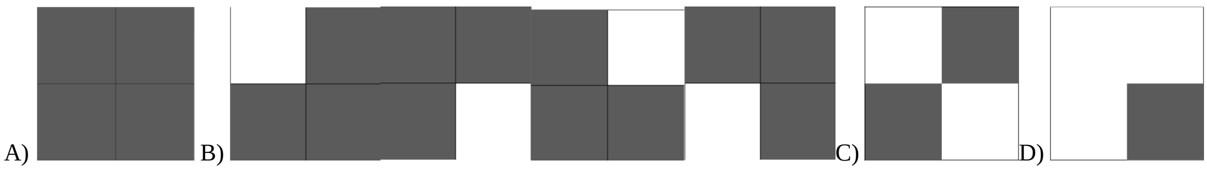


Figure 1 – Image of the detector 2 on 2. The gray areas correspond to the pixels in which the photons hit.

The highest probability event is three pixels in which photons hit and one vacant or empty pixel. Such distribution of active and vacant pixels is typical for uniform illumination.

The probability that a single pixel of the detector will not be hit by a photon is equal:

$$k = \left(1 - \frac{1}{LH}\right)^F, \quad (3)$$

where k is the ratio of vacant pixels.

The number of vacancy pixels depends on the number of photons or on the power factor x. It follows from the dependence that when the number of photons is equal to the number of pixels, the vacancy factor does not depend on the detector size. If the number of photons is greater than the number of pixels, then the vacancy factor increases with increasing detector size. In the limit with infinitely large detector the vacancy factor is zero:

$$\lim_{LH\to\infty}\left(1-\frac{1}{LH}\right)^{F}=0\,,\,x>1\,, \tag{4}$$

if the number of photons is less than the number of pixels, the vacancy factor decreases as the detector size increases. In the limit with infinitely large detector the vacancy factor is equal to one:

$$\lim_{LH\to\infty}\left(1-\frac{1}{LH}\right)^{F}=1,\,x<1 \tag{5}$$

Experiments on registration of photons of X-ray range by means of two digital cameras with resolution 480x640 and 240x320 were perfomed. Experimental images are shown in Figure 2. The images contain clearly visible peaks, which correspond to the X-ray photons. Numerical methods have been used to perform thresholding, highlighting the X-ray photons in the image.

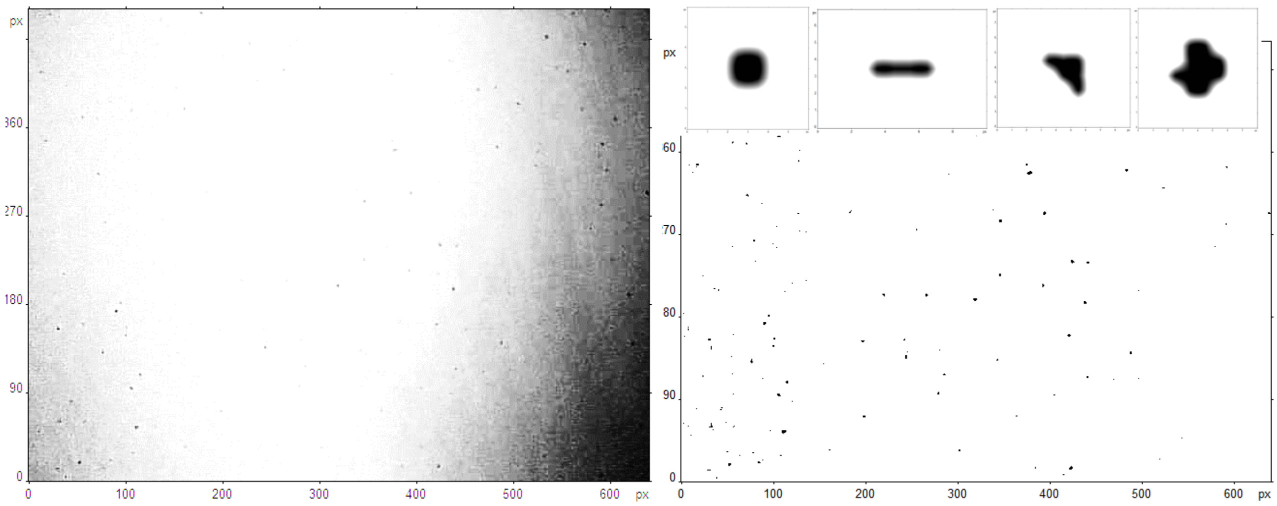


Figure 2 – Experimental image of the camera with 480x640 resolution at X-rays.

According to the results of the experiments, it is possible to register some areas (whose size is determined by the pixel size of the camera matrix and photon energy) in which the X-ray photons hit. Following a graphic processing was performed, the background obtained when the X-ray source was turned off was subtracted from the images and then a threshold processing was applied, the types of different hits in the matrix are shown in Figure 2. In the image we see several peaks with different symmetries and sizes.

The results of experiments on detection of uniform X-ray radiation by a digital CCD camera show that the registration of individual photons has a local nature in the form of peaks, differing in symmetry and size.

The work is partly supported by the Ministry of Education of the Republic of Belarus within the framework of task 3.07 GPNI "Mechanics, metallurgy, diagnostics in mechanical engineering", subprogram "Technical diagnostics".

Reference

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