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ScienceDirect

Physics Procedia 84 (2016) 189 – 196

Physics Procedia

International Conference "Synchrotron and Free electron laser Radiation: generation and application", SFR-2016, 4-8 July 2016, Novosibirsk, Russia

Upgrade of the detector for imaging of explosions.

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Abstract

Methods of dynamic imaging of explosions at a synchrotron radiation (SR) beam and small-angle X-ray scattering experiments with exploding samples are being developed in the Siberian Synchrotron Radiation Center (SSRC) at the Budker Institute of Nuclear Physics for more than fifteen years. The detector for imaging of explosions (DIMEX) was developed for these purposes and successfully operating at the beam line 0 at the VEPP-3 storage ring and at the beam line 8 at the VEPP-4M storage ring. The DIMEX is based on gas technology and allow to measure SR flux as a function of position and time with spatial resolution of ~200 μm (FWHM), maximum frame rate of 2 MHz and time resolution of ~80 ns. Maximum value of the SR flux that can be measured by the present detector corresponds to ~5000 photons/(channel*bunch) (20 keV average energy, channel area 0.1x0.5 mm^2, bunch revolution frequency 4 MHz). Maximum number of frames that can be stored in the present detector is 32 and the number of channels with 0.1 mm width is 512. In order to significantly improve the precision of data obtained by the DIMEX an upgrade of the detector has been started. The electronics of the gaseous version of the detector has been changed such that the new detector is able to operate with frame rate of 8 MHz and store data in up to 100 frames. A new ASIC was developed for this purpose called DMXG64A that includes 64 channels with low noise integrator and 100 analogue memory cells in each channel. Input charge can be stored to and read out from analogue cells with maximum frequency 10 MHz. This new version of the detector is called the DIMEX-G and is planned to be used at the VEPP-3 storage ring and for SAXS studies at the VEPP-4M storage ring. For imaging of explosions at the beam line 8 at the VEPP-4M storage ring, where SR flux is expected to be about 10-100 times higher than at the VEPP-3, a new detector based on Si micro-strip technology is being developed. Si micro-strip sensors with special design have been manufactured by Hamamatsu Photonics company. Each sensor contains 1024 30mm long strips with 50 μm pitch. The sensor thickness is 320 μm and it will be positioned at an angle of 1.7 degrees with respect to the SR beam plane in order to get effective Si thickness along the beam close to 10 mm. The new detector called DIMEX-Si will have spatial resolution of 50 μm (FWHM) and time resolution close to 10 ns. The new ASIC is under development for this project that will allow to operate with the frame rate of 50 MHz and record maximum charge that corresponds to the flux close to 10^6 photons/(chan*bunch), i.e. about 100 times higher than with present detector.

Peer-review under responsibility of the organizing committee of SFR-2016.

Keywords: synchrotron radiation, time resolved studies, silicon strip detector

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Peer-review under responsibility of the organizing committee of SFR-2016.
doi:10.1016/j.phpro.2016.11.033

1. Introduction.

Technique of direct imaging of exploding samples with a synchrotron radiation (SR) beam as well as recording of small angle X-ray scattering (SAXS) from an exploding sample is being developed in the Budker Institute of Nuclear Physics and Siberian Synchrotron and TeraHerz Radiation Center for more than 15 years [1]- [5]. These methods utilize remarkable time structure of SR that consists of very short flashes (less than 1 ns in case of VEPP-3 and VEPP-4M storage rings) following at equal time intervals of several tens to hundreds nanoseconds. At present the specialized one-dimensional detector DIMEX (Detector for IMaging of EXplosions) is being used for fast dynamic imaging [6]- [8].

Schematic view of these experiments is shown in Fig. 1. SR beam from the wiggler goes through the collimator unit where narrow flat beam is formed. Then the beam passes through the explosion chamber with 2mm thick Be windows followed by special dumping diaphragms after the inlet window and before the outlet window. The explosion chamber at VEPP-3 beam line 0 allows for exploding up to 50 g of trinitrotoluene (TNT) or equivalent. After the explosion chamber the beam gets into the detector hutch with the fast shutter that opens the beam only for ∼100 μs during an experiment, and then hits the detector. The goal of these type of experiments is either to restore the density variations in an exploding sample with time scale of hundreds ns, or to find the variation of size and density of nano-particles in an explosion([10, 11, 12]).

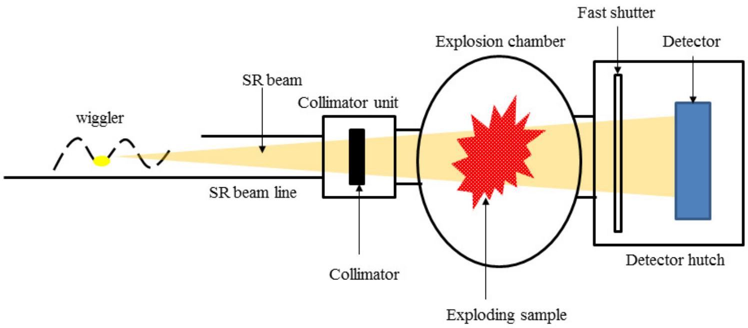

Fig. 1. Schematic view of the experiment for direct imaging of exploding sample.

DIMEX is an ionization chamber filled with Xe-CO_2(75%-25%) at 7 atm absolute (Fig. 2). SR beam hits sensitive gas volume through 1 mm beryllium window in the gas box and is absorbed in the gap between the drift electrode and Gas Electron Multiplier (GEM) that serves as a Frisch grid. The GEM is operating in attenuation mode when electron flow is reduced due to limited GEM transparency. Electrons of primary ionization from the interaction gap are partly penetrate through the GEM and induce signals at the readout strip structure that consists of 512 strips with 100 μm pitch. The strip structure as well as the interaction gap are 30 mm long and thus the detector has ∼50% detection efficiency for photons with average energy of 20 keV. The readout strips are connected to APC128 front-end chips [9] that integrate charge from each bunch and store these data in an analogue memory. The data from a sequence of 32 bunches are readout to the computer after the end of experiment. All details about the design and operation of the DIMEX can be found in [5, 6, 8]. The present version of DIMEX has ˜200 μm spatial resolution (FWHM) for 20 keV X-rays, can detect signal equivalent to ∼5000 20 keV photons at most from a single bunch in each channel (∼4×10^{11} ph/mm^2s) and can store frames with maximum frequency of 2 MHz.

The present DIMEX parameters are at the limit of gas detector technology. Maximum signal from a single bunch is limited due to accumulation of ion space charge in the sensitive gas volume. Spatial resolution is determined by diffusion of electrons during their drift towards the readout strip structure. The frame rate is limited by the front-end chip and can be significantly improved with the development of new faster ASIC. For further increase of maximum detectable signal and signal-to-noise ratio as well as for the improvement of spatial resolution it was proposed to change the detector technology and make the DIMEX based on Si microstrip sensor. In this paper we describe the development of new gas version of the detector with a new ASIC, that allows to increase the frame rate up to 10 MHz,