Application Example of APDCAM in a Scintillator Measurement for Detecting Fast Ions in a Magnetic Fusion Experiment

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Measuring the population of fast ions in a controlled magnetic fusion experiment can be done using the Fast Ion Loss Detector (FILD) technique. The scheme is shown in *Figure 1.* The scintillator head is a closed box with a small hole on one side. This head is placed close to the hot plasma where fast ions are expected. These ions travel in a curved tracetory in the magnetic field of the experiment and penetrate the box through the hole. They fall at different places onto the scintillator depending on their energy and the angle of their velocity. The ion impact produces light which is observed through an optical system with some kind of detector. The light distribution on the scintillator gives information on the energy and velocity direction of the ions. The intensity of the incoming ions is often modulated in time at high frequency, up to 1 MHz.

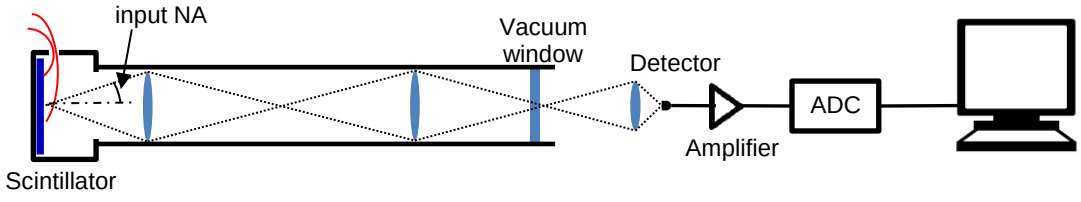

Figure. 1. Scheme of the Fast Ion Loss Detector (FILD) measurement.

As detector a camera can be used, which gives the fine spatial resolution of the light. However, it cannot detect the high frequency modulation, therefore a set of (20-30) optical fibres are used to collect light from larger areas on the scintillator and measure the high-frequency modulation with photomultipliers. A block of 20-30 photomultipliers is difficult to build, bulky and sensitive to magentic fields, therefore should be placed far from the device at the end of long optical fibres. Additionally, photomultipliers are not very sensitive, can detect only 10-20 percent of the incoming light.

Recently special CMOS cameras also became available where by reading information only from a small Reagion of Interest (ROI, e.g. 64x64) on the sensor high frame rates can be achieved, up to 1 MHz. One would think these cameras can be used for measuring the high-frequency modulation of the scintillator light with much better spatial resolution and with less effort than the photomultipler system. Unfortunately this is not the case. Due to the small pixel size of the camera a 64x64 pixel ROI means typically a less than 1x1 mm area on the sensor. The size of the scintilllator is typically 50 mm, therefore the image has to be demagnified by a factor of 50. Due to basic imaging rules the product of the image size and the Numerical Aperture (half angle of light cone) is constant throughout the optical system. This means on the detector NA is 50 times higher than the input NA on the scintillator. A practical optical system cannot have considerably higher NA than unity, which means the input NA is limited to about 1/50 in the case of the camera measurement, seriously limiting the amount of input light which depend on the square of the NA. Although the camera can indeed measure fast, the low amount of light limits the available imaging frequency.

This problem was overcome by APDCAM detector cameras from Fusion Instruments. The standard 4x8 and 8x8 pixel APD matrix in these cameras have about 10x20 or 20x20 mm size, which means only a factor of 2 demagnification is needed. This increases the sensitivity by a factor of ast least by hundred compared to a fast CMOS camera. Additionally APDCAM has over 80% quantum efficiency thus better sensitivity than the photomultiplier system. The sustained sampling frequency in APDCAM can be up to 6 MHz, more than enough for the measurement. This device was easy to integrate in to the FILD measurement as it needs only a mains and fibre optics communication cable and comes in magnetic field hardened version as well, thus can be installed directly at the fusion experiment. Such a system has been set up with an APDCAM-1G camera on the ASDEX Upgrade tokamak in Garching bei München, Germany. A second system is under construction using an 8x8 pixel APDCAM-10G camera. These system provide efficient detection of the scintillator light with 2 MHz sampling frequency during the whole 5 s discharge of the tokamak device.

Recently new improved Multi Pixel Photon Counter (MPPC) detectors from Hamamatsu are available and can be installed into APDCAM or even mixed systems are possible. (For a comparison of APDs and MPPCs see the white paper on the Fusion Instruments website.)