Low Cost Alternative of High Speed Visible Camera for Tokamak Experiments

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A high speed visible camera is a standard diagnostic tool for the most of the magnetic confinement fusion experiments. These cameras serve for a wide range of purposes including measurement of emissivity profiles of hydrogen isotopes and certain impurities, visualization of transient events in the edge and scrape-off layer plasmas, monitoring the status of plasma facing components etc. Generally, a set-up providing high spatial resolution and the high framing rate of at least 1 kHz is required to address the most of these tasks. Compatibility with high magnetic fields and non-negligible radiation doses can be an issue when applying this type of diagnostic at certain fusion experiments. The relatively high price is one of the main disadvantages of the commercially available solutions possibly being even prohibitive when considering installation of such products at a small university based fusion experiments.

In our contribution we plan to present design, analysis, and performance evaluation of a new low cost high speed visible camera diagnostic system based on the camera Casio EX-F1, with the price in the range of a few thousands USD. The achieved temporal resolution is up to 40 kHz. Such high temporal resolution was obtained through so called "rolling shutter" effect caused by sequential read out of the CMOS detector. This new diagnostic was successfully implemented and tested on a university based tokamak experiment GOLEM ($R = 0.4$ m, $a = 0.085$ m, $B_t < 0.5$ T, $I_p < 4$ kA). GOLEM is a small iron core, ohmically heated tokamak with the main missions to contribute to the education and training of a new generation of fusion scientists and to study certain innovative concepts particularly in the area of fusion plasma diagnostics and technology.

The presented low cost alternative of the high speed visible camera proved to be a versatile diagnostic tool with a number of potential applications. The first discussed application is a tomography in the visible spectral range using two perpendicular cameras for estimation of plasma position and emissivity profiles of various plasma species. The second application is a visible light spectroscopy for impurity studies with a high temporal resolution. Possible issues arising from application of the camera in tokamak environment were investigated and possible corrections are proposed.

[1] V. Svoboda et al., "Former tokamak CASTOR becomes remotely controllable GOLEM at the Czech Technical University in Prague," *37th EPS Conference on Plasma Physics*, (2010)

[2] V. Svoboda et al.," Multi-mode remote participation on the GOLEM tokamak*", Fusion Engineering and Design*, 2011, Elsevier