Beam Halo Monitor Based on an HD Digital Micro-Mirror Array

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Abstract

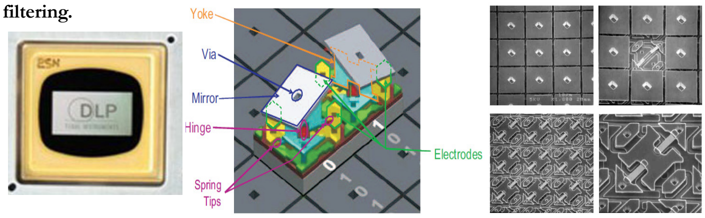
A beam halo monitor is an essential device to pursue studies of halo particles produced in any particle accelerator as to investigate the effects of disturbances, such as field kicks, gradient errors, *etc.* A fast, least intrusive, high dynamic range monitor will allow the detection and potentially control of particles at the tail of a transverse beam distribution. Light generated by a beam of charged particles is routinely used for beam diagnostic purposes. A halo monitor based on a digital micro-mirror device (DMD) used to generate an adaptive optical mask to block light in the core of the emitted light profile and hence limit observation to halo particles has been developed in close collaboration with CERN and University of Maryland. Here, an evolution of this monitor is presented. A high definition micro mirror array with 1920x1080 pixels has been embedded into a MATLAB-based control system, giving access to even higher monitor resolution. A masking algorithm has also been developed that automates mask generation based on user-definable thresholds, converts between CCD and DMD geometries, processes and analyses the beam halo signal and is presented in detail.

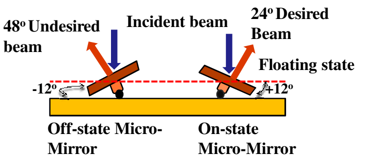
Introduction

For any high intensity accelerator, it is of central importance to have a detailed understanding of the beam halo formation to possibly control and detect beam losses. The latter are associated with potentially negative effects, such as activation of the surrounding vacuum chambers, emittance growth, increased signal background and therefore complicate machines maintenance and increase costs.

HD-DMD Technology

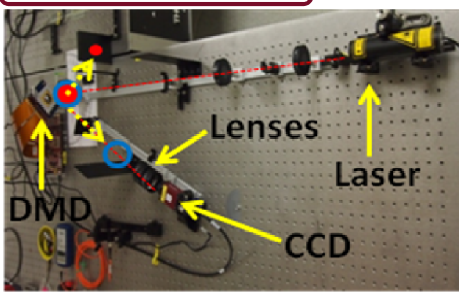
The halo monitor is based on micro-opto-electromechanical system (MOEMS) technology known as Digital Micro-mirror Device (DMD). The DMD uses the DLP Discovery 4100 platform with a 0.95 1080p chipset created by Texas Instruments for enabling high-definition and high performance spatial light filtering.





The device is used as an adaptive optical device where each mirror in the DMD can be controlled individually to direct light in different directions depending on the micro mirror state

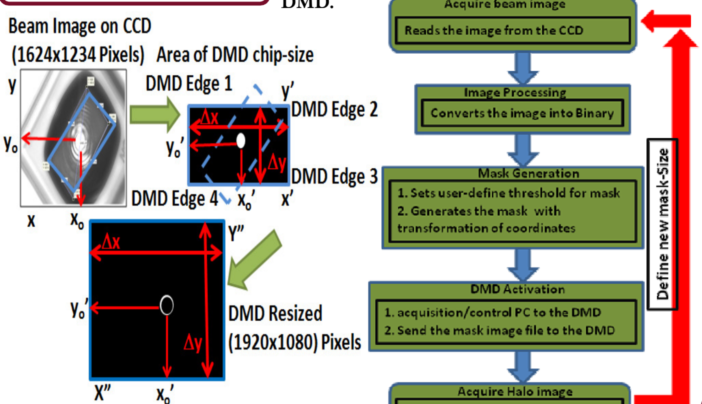
Experimental Setup



A laser with an output power of $0.5mW$ and a single wavelength of 633nm is ideal for a proof-of-principle experiment, as the opening angle of the laser of 0.1° is comparable to the OSR/OTR emitted by an electron beam at some 100MeV.

Mask Algorithm

A MATLAB program was written to control the CCD and to generate a mask to be sent to the DMD.



The DMD mask calibration procedure

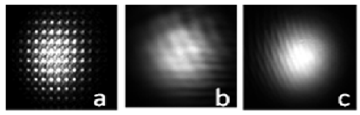
Mask Generation

The HD-DMD is fundamental in the mask generation process as it operates as the programmable spatial filter for a desired beam shape.

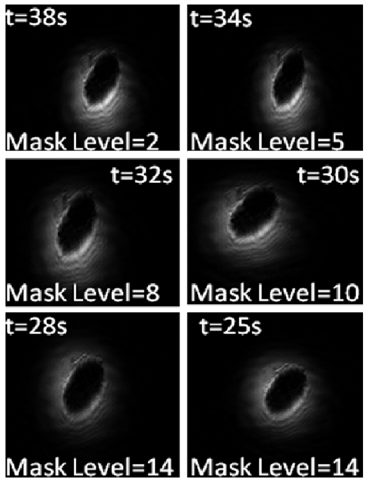
A beam image is provided from the CCD, read into a mask generation code in MATLAB. The stored image is converted to gray-scale. Now an adaptive mask is then created and applied to the beam core. The mask info is then sent from the control PC to the DMD to flip the mirrors. Now the central beam core will be deflected, while the halo is observed in the CCD sensor.

Measurements

The HD-DMD acts as a 2-D optical grating that creates diffraction pattern.



The exposure time is varied inversely proportional to the mask threshold level for each measurement to achieve an optimum result. Increased exposure times will increase light intensity after each mask is applied.



Conclusion

This paper presented the mask generation process and the proof-of-principle setup of a halo monitor using state-of-the-art HD-DMD technology. The beam halo monitor and first results obtained in a laboratory setup at the Cockcroft Institute, UK were discussed. Initial results indicate access to a dynamic range of better than 10^6, opening up interesting opportunities with the high-resolution micro-mirror array. Future experiments are planned at the University of Maryland Electron Ring (UMER), where the HD-DMD shall be used in combination to existing halo monitors to study beam halo dynamics in special beam regimes.

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