Development of a Beam Halo Monitor based on HD-Digital Micro Mirror Array Technology

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Abstract

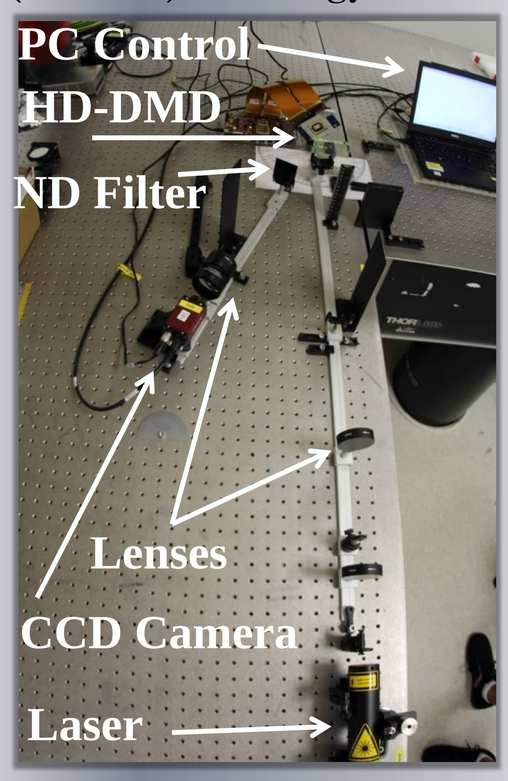
Beam halo monitoring is an essential device to measure the halo's produced in any particle accelerator. These halo particles are associated negative effects such as emittance growth , space-charge, *etc.* An ideal candidate to detect and possibly control halo particles at the tail of a transverse beam distribution is a monitor based on a high-definition digital micro-mirror device (HD-DMD) technology. The HD-DMD based halo monitor uses the exploitation of light generated by charged particle beams routinely used for beam diagnostic purposes, to program an adaptive optical mask to filter light in the core of the emitted light profile and hence observe the halo particles with minimum limitation. This monitor has been developed in close collaboration with CERN and University of Maryland and is a fast, least intrusive and that can achieve high dynamic range measurements. This contribution presents a HD-DMD with 1920x1080 pixels, that has been embedded into a LabView-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, interfaces between CCD and DMD geometries and analysis of the imaged beam halo is presented.

MOTIVATION

- Innovative diagnostic methods are required to monitor the beam's halo as most of the existing techniques are unable to measure the beam tail and halo distribution with a High Dynamic Range of >10e6.
- An ideal candidate for beam halo profiling is a HD-DMD technology based beam profile monitor.
- This is a promising method for providing knowledge on beam losses which originate in the low-density halo that extend far from the beam core.

HALO MONITOR

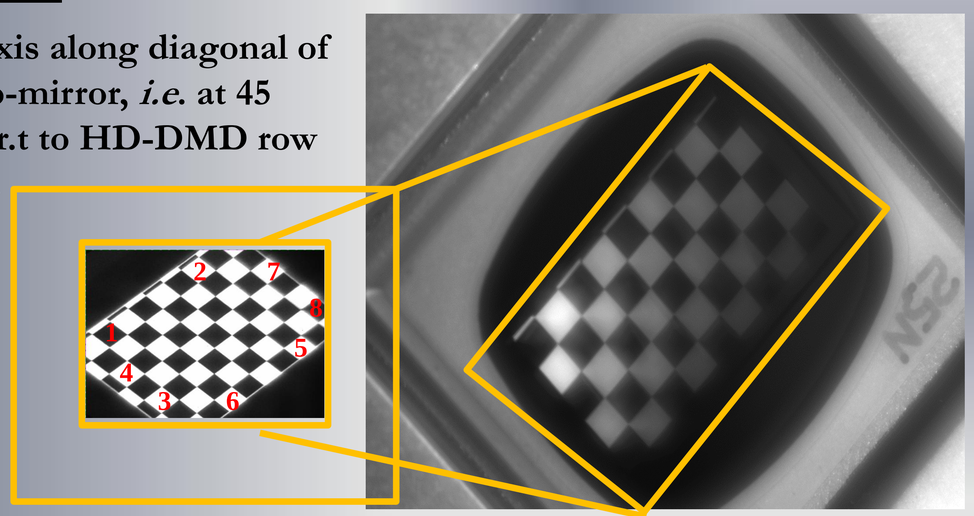
- The halo monitor is based on micro-opto-electromechanical system (MOEMS) technology known as Digital Micro-mirror Device (DMD).



- The DMD is the core component of the halo monitor.
- The CCD camera images the beam profile filtered by the DMD.
- The DMD device is used as an adaptive optical device.
- Each mirror pixel in the DMD can be controlled individually to direct light in different directions depending on the micro mirror state.
  - DMD micro-mirrors have three possible states:
  - all floating, flat state (no power)
  - two independent assignable + or - 12^0 states (power on)

CALIBRATION

- Rotation axis along diagonal of each micro-mirror, *i.e.* at 45 degrees w.r.t to HD-DMD row or column.

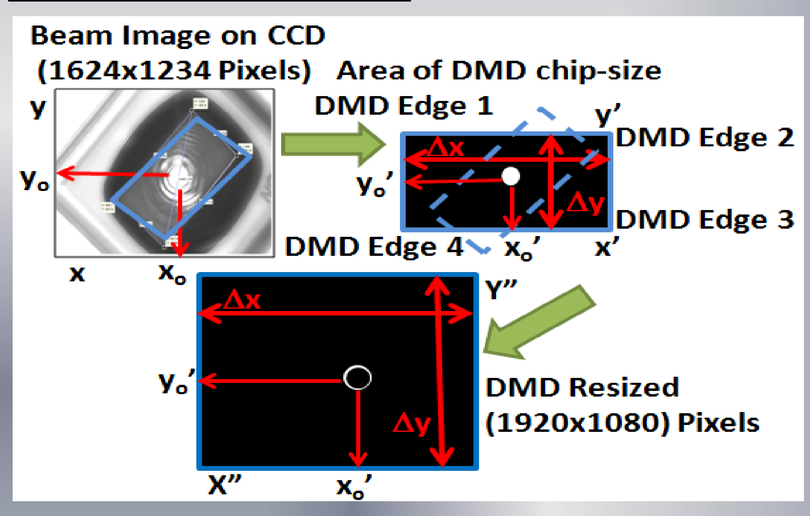


8- points of reference for defining the DMD location inside the CCD image.

- Load reference image
- Define 8 points
- Save reference values
- Load beam image
- Apply mask routine
- Load masked image

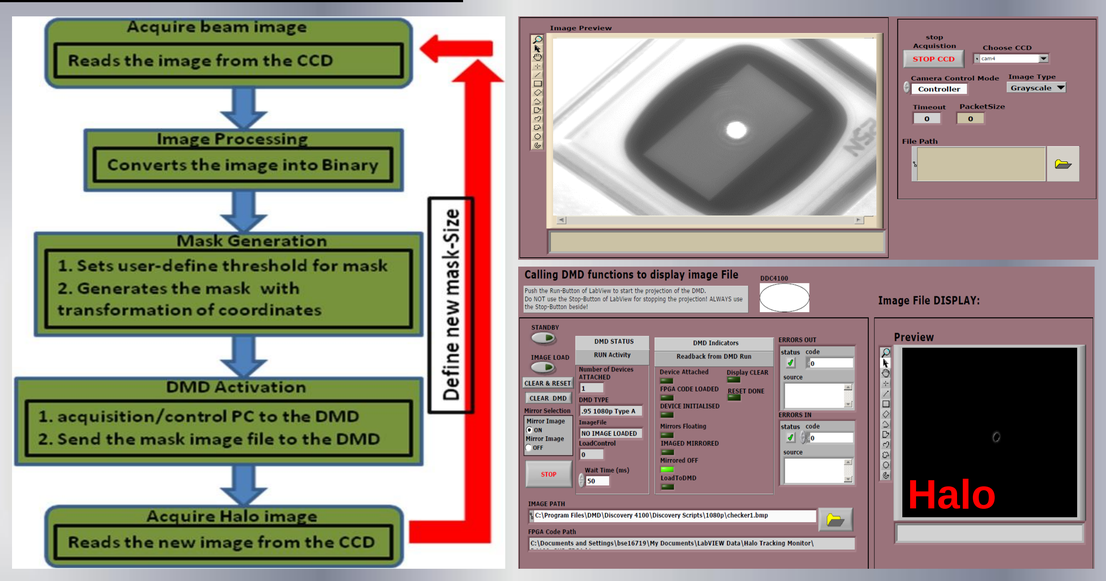
A LabView GUI program for the calibration of the DMD area to localise the mask region define to a specific beam shape.

MASK GENERATION



- Mask adapting
- Information transfer from CCD to DMD
- Define DMD area
- Set mask limit or size

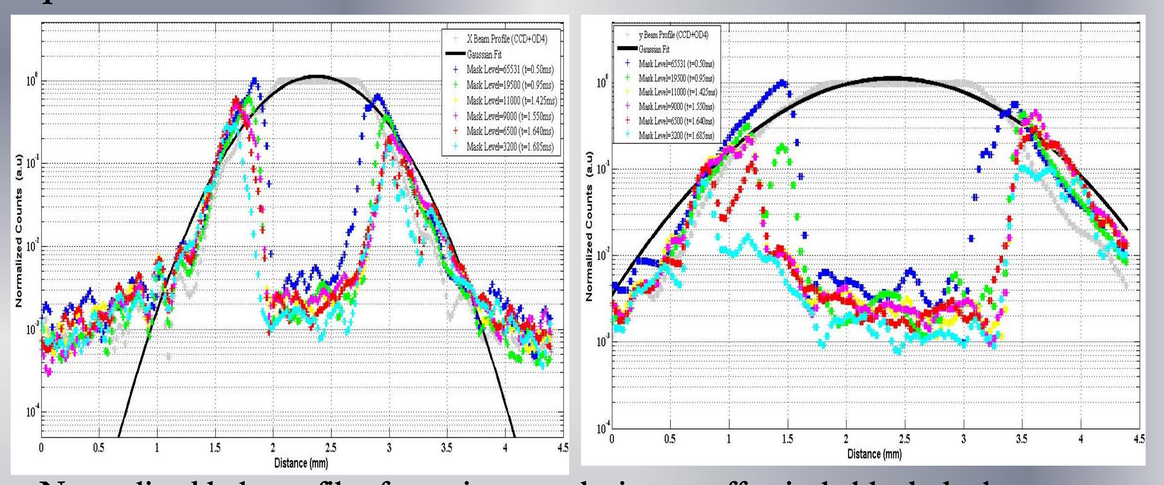
SOFTWARE OPERATION



A LabView control program of the Halo Monitor for Mask-Generation

MEASUREMENTS

- From a geometrical perspective:
  - Define the halo as the area that contains all particles outside the Gaussian shaped beam core.
- To increase DR, mask threshold levels needs to be larger and then exposure time scaled and extended.



Normalized halo profiles for various mask sizes to effectively block the beam core.

SUMMARY

- The HD-DMD based Halo Monitor is versatile and adaptable to any accelerator.
  - For high or low intensity, energy or any particle species.
- The adaptive optical mask can block any core for various beam shape or size.
- The HD-DMD can be used in combination to existing halo monitors to study beam halo dynamics in special beam regimes.

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