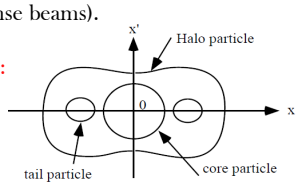
A Novel Adaptive Halo Monitor based on HD Micro-Mirror Technology

B.B.D. Lomberg[1], C.P. Welsch[1] and B. Bolzon[2],
[1]Cockcroft Institute and the University of Liverpool, UK
[2]CERN, BE/BI Group, Geneva, CH

Abstract

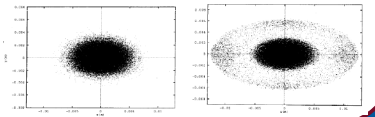
The detection and potential control of the beam halo is a *essential* parameter to be *measured* in high-energy accelerators (or low-energy machines with intense beams).

"Beam Halo" is associated with many negative effects, such as:
Unwanted particle losses lead to nuclear activation,
Increase in *secondary emission, Space-charge.*
Or even damage of the surrounding vacuum chamber.



An **ideal monitor** is required to *observe* how to *minimise* the number of particles in the *tail region* of the beam distribution.

What is 'Halo'? -> No *pure* definition?
Lets set criteria for halo particles...
Low density portion of the beam where particles are at large radii.
Very low intensity distribution which is difficult to measure within close proximity to the more intense core part of the beam.

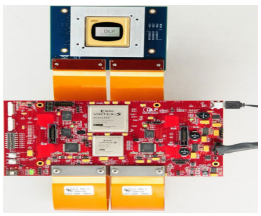


Introduction

Experimental measurement of the halo particles is an important tool study for accelerators, but a clear measurement technique still needs to be developed. A new adaptive masking method is developed to image beam halo, which uses a digital micro-mirror-array device (DMD) technologies. The halo is very hard to characterize because of its low intensity, which requires a high accuracy and a measurement system with a high dynamic of range (≥10^5).

Halo Monitor Development

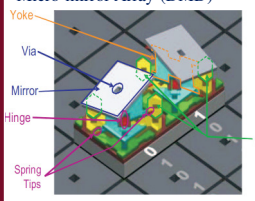
The novel diagnostic device using a adaptive masking method to image the beam halo can provide high sensitivity as well as a high dynamic range, which can be exceeded by at least an order of magnitude, *i.e.* **DR** ~ 10^6.

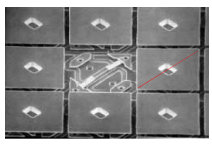


- 1920 x 1080 array *Al* micro-mirror [Discovery 4100]
- DMD dimensions 14.4x10.8 mm (0.95" Micro-Mirror Array diagonal)
- USB Interface 64-bit @ 400 MHz for data transfer
- up to 23.148 full array mirror patterns / sec (48 GBs)

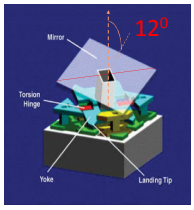
Adaptive Mask using Digital Micro-mirror Array (DMD)*

*DLP™ Texas Instruments Inc.

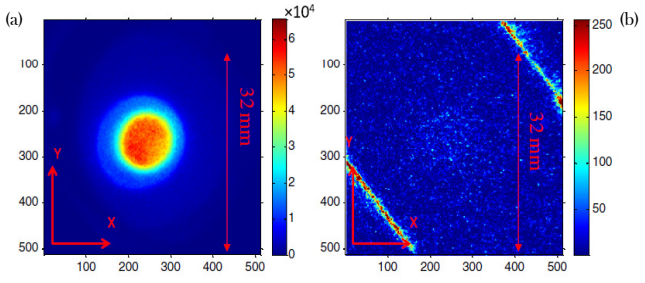




10.8 um

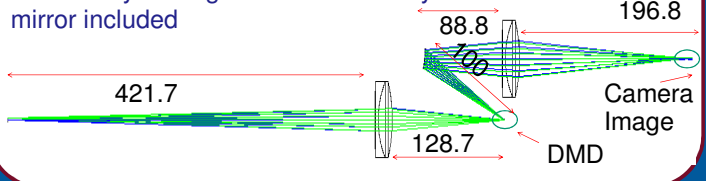


The DMD forms the core of the detector and is used to generate a mask that is adapted to the shape of the beam to be analyzed. First, (a) the profile of the beam is measured with all mirrors activated, so that all light is detected by the camera.



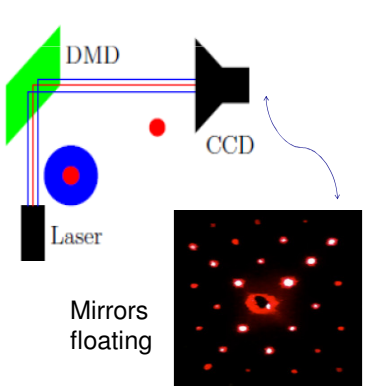
The micro mirrors of the DMD can only be set to two different states, the gray scale image needs to be converted into a binary image to define the mask. The threshold value that decides on whether a pixel belongs to the core or the tail distribution can be set freely. This binary image is then sent to the DMD and defines the position of the mirrors. In a final step, (b) the image is the re-measured with the mask by increasing the integration time of the camera and an image with an increased dynamic range is obtained.

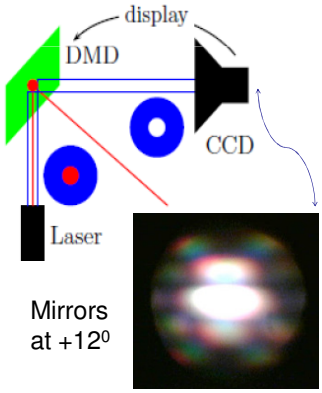
✓Zemax ray-tracing: reflection done by the DMD and the mirror included



Proof-of-Principle

The imaging method used is flexible, easy to setup and can be used at any accelerator or light source.

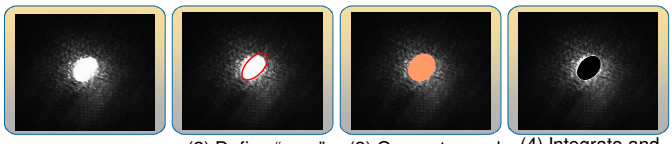




The DMD behaves like a 2D optical grating. If illuminated by a single wavelength laser source, a grid- like diffraction pattern will be observed. When all the micro-mirrors are rotated by +12° the DMD becomes a blazed grating

How the algorithm works?

Basic Idea of the adaptive mask using DMD is exploiting light produced by the beam which is first imaged onto the array; then an adaptive mask is created and applied to filter out the beam core; and the result is reimaged onto an CCD camera.



(1) Image onto DMA (2) Define "core" (3) Generate mask to block "core" (4) Integrate and Reimage Halo

Development of the masking algorithm in MatLab is done by selecting discrete points on the beam image as a first step, then defining the core by specifying a particular geometric area. Thereafter, setting an intensity threshold to define the "core". The post image processing is achieved using a 1624x1234 matrix with a range of values between 0 and 4098 for a 12bit CCD.

References

❖R. Fiorito *et. al.*, "Optical Synchrotron Radiation Beam Imaging with a Digital Mask", Proceedings of BIW2012, Newport News, Virginia, USA., TUPG031.
❖H. D. Zhang *et. al.*, "Beam halo imaging with a digital optical mask", Phys. Rev. ST Accel. Beams 15, 072803 (2012).
❖H. Zhang *et. al.*, "Beam Halo Measurements using Adaptive Masking Methods and Proposed Halo Experiment", 52nd ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams, HB2012.
❖H. D. Zhang *et. al.*, "Beam Halo Measurements at UMER and the JLAB FEL using an Adaptive Masking Method", Proceedings of 2011 Particle Accelerator Conference, New York, NY, USA., WEOCN5.

Acknowledgements

This work is supported by the European Union under contract PITN-GA-2011-289485 and by STFC under the Cockcroft Institute Core Grant No. ST/G008248/1.

http://www.cockcroft.ac.uk
http://www.quasar-group.org
Blaine.Lomberg@liverpool.ac.uk