Recent advances in MicroScint beam profiler technology

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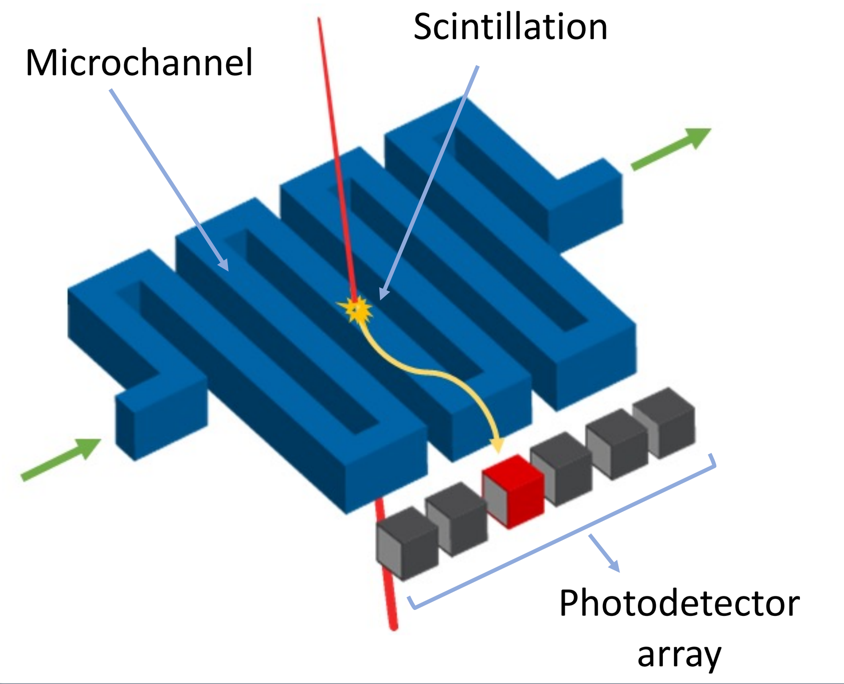
Beam instrumentation and diagnostics are crucial to verify beam parameters (e.g. centroid, beam size, relative beam intensity and beam transverse emittance) on a regular basis so to adjust machine settings and also to maximize accelerator uptime. Here we illustrate some recent advances based on the so-called MicroScint, a technology implemented by CERN and EPFL in recent years. We present microfabricated beam profilers with a spatial resolution up to ~30 µm, a net improvement compared to commercial scintillating fiber-based devices, limited to the minimum available size of 250 µm.

The developed detectors are designed to suit all types of proton or heavy ion accelerators, namely cyclotrons, synchrotrons, and linacs for beams starting from tens of MeV, DC or pulsed. In particular the simulations focused on a proton-therapy beam with typical intensity of 1.5·10^9 protons/s. The presented beam detectors could also be used for dosimetry, X-ray imaging or for fundamental physics experiments such as the generation of vortex beams and more generally for providing a novel diagnostic tool for experiments aimed at manipulating the wavefunction of fundamental particles.

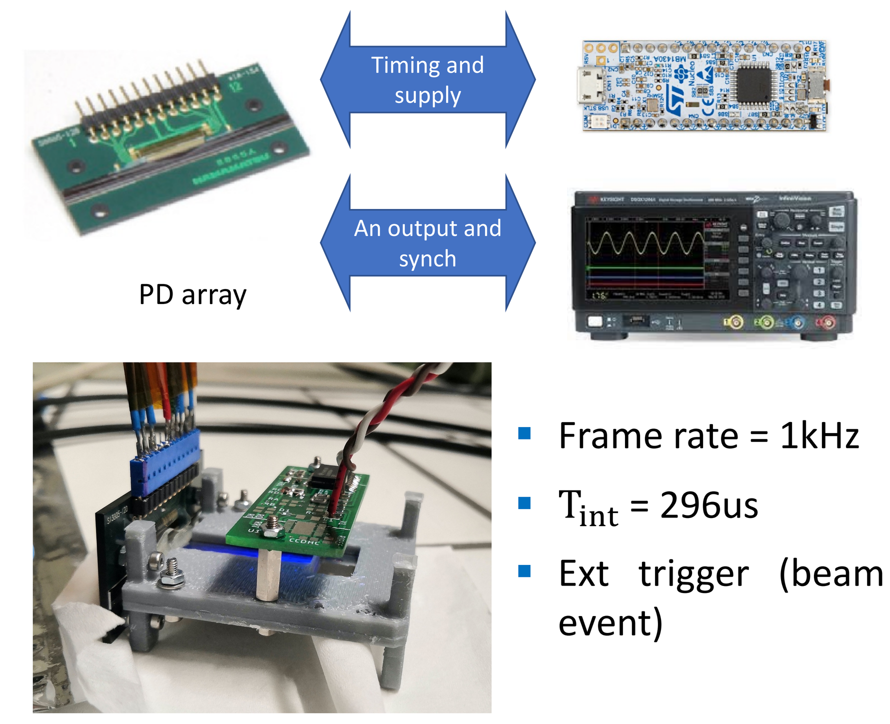
MicroScint technology



- Microfabricated silicon channel coated with Aluminium and filled with a scintillating liquid (EJ-309), defining an array of waveguides [1]
- Scintillation light guided along the microchannel and detected
- Photodetectors coupled to each channel end
- Potential advantages with respect to scintillating fiber-based devices (smallest available = 250 um) [2-3]

Measurements set-up

- Readout: Photodiodes (PD) array (S13885-128) with same pitch of the microchannel waveguides (400 um)
- PCB with UV LEDs (λ=277 nm) illuminating the detector
- 3D-printed mechanical holder for detector and electronics
- Microcontroller (NUCLEO-G431KB) generating all timings + ADC (not yet implemented)
- Oscilloscope acquisitions of PD analog serial output and post-processing



- Frame rate = 1kHz
- T_{int} = 296us
- Ext trigger (beam event)

Fig. 5 Assembly of detector, PD array and UV led PCB

Devices fabrication

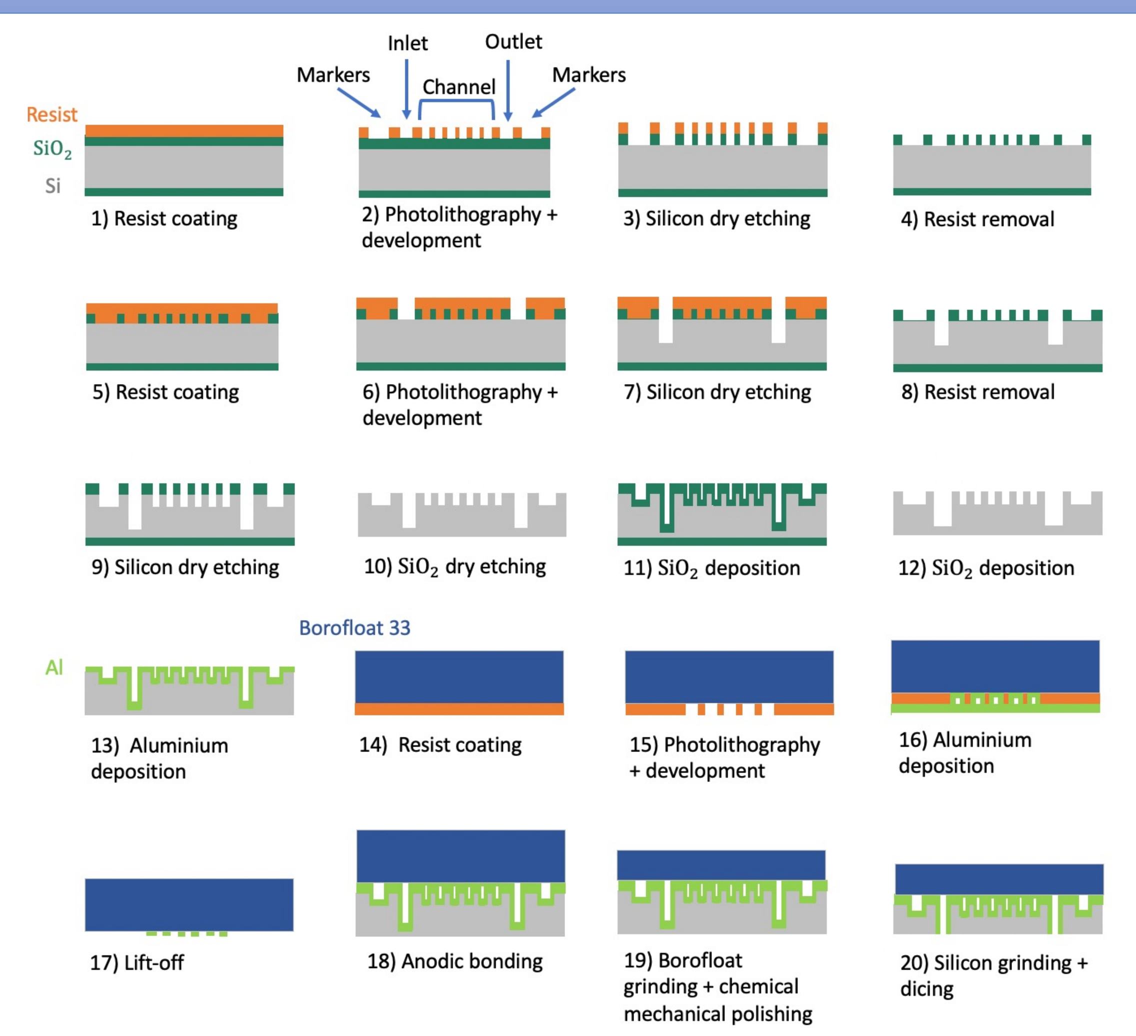


Fig. 1 Process flow performed with standard microfabrication techniques.

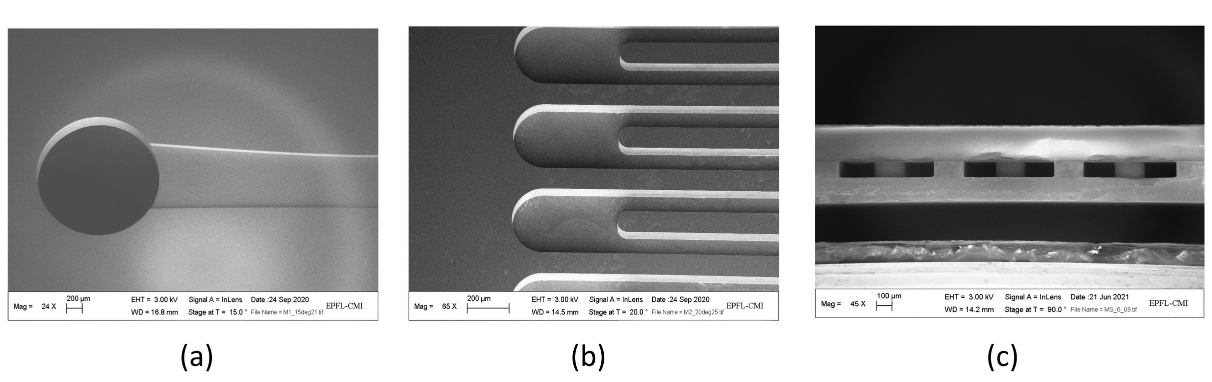


Fig. 2 SEM images after (a) the etching of the inlet and outelt (step 8), (b) the etching of the channels (step 10). and (c) the dicing (step 20) to open the extrimity of the channels allowing photons to escape.

- Channel width: 50 um ÷ 200 um
- Pitch: 100 um ÷ 400 um

→ Spatial resolution: 30 um÷115 um

Calibration test with UV LEDs

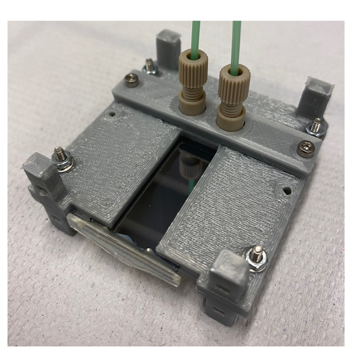
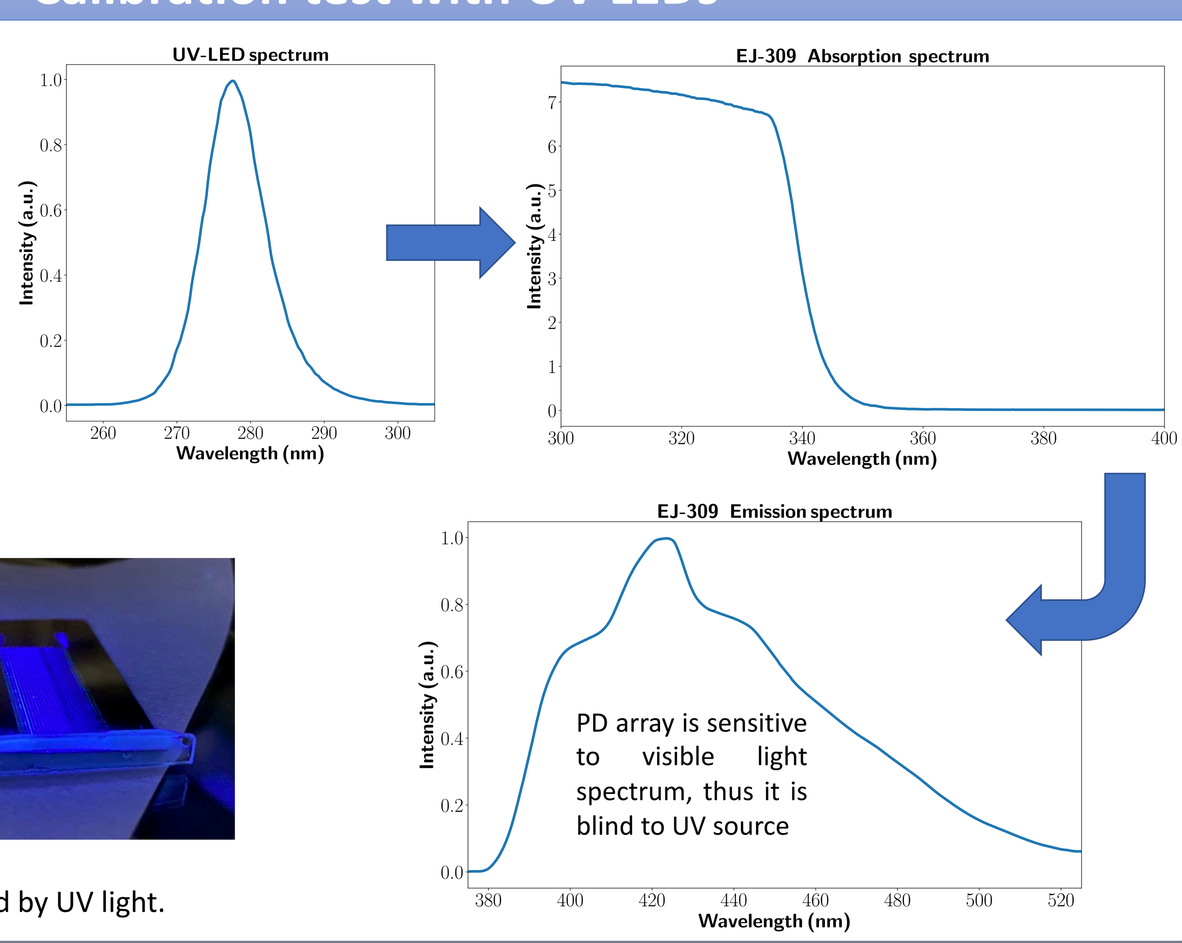


Fig. 3 Setup to fill the device with the EJ-309 scintillating liquid [4].



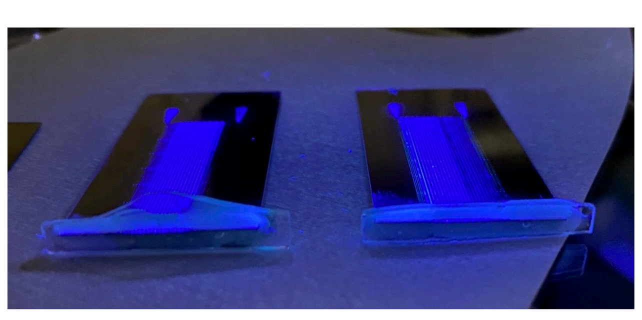


Fig. 4 Final devices illuminated by UV light.

Experimental results

- Detector active area: 30 x 10 mm^2, channel width 200 um, segments pitch 400 um, total thickness 480 um.

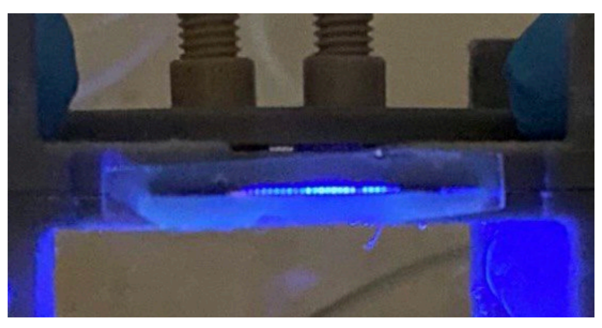
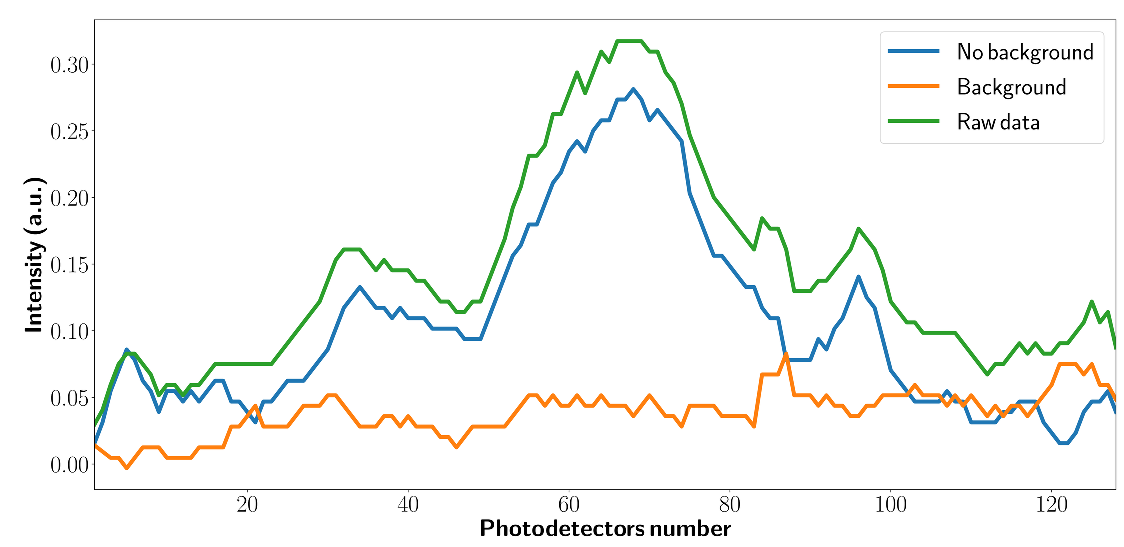
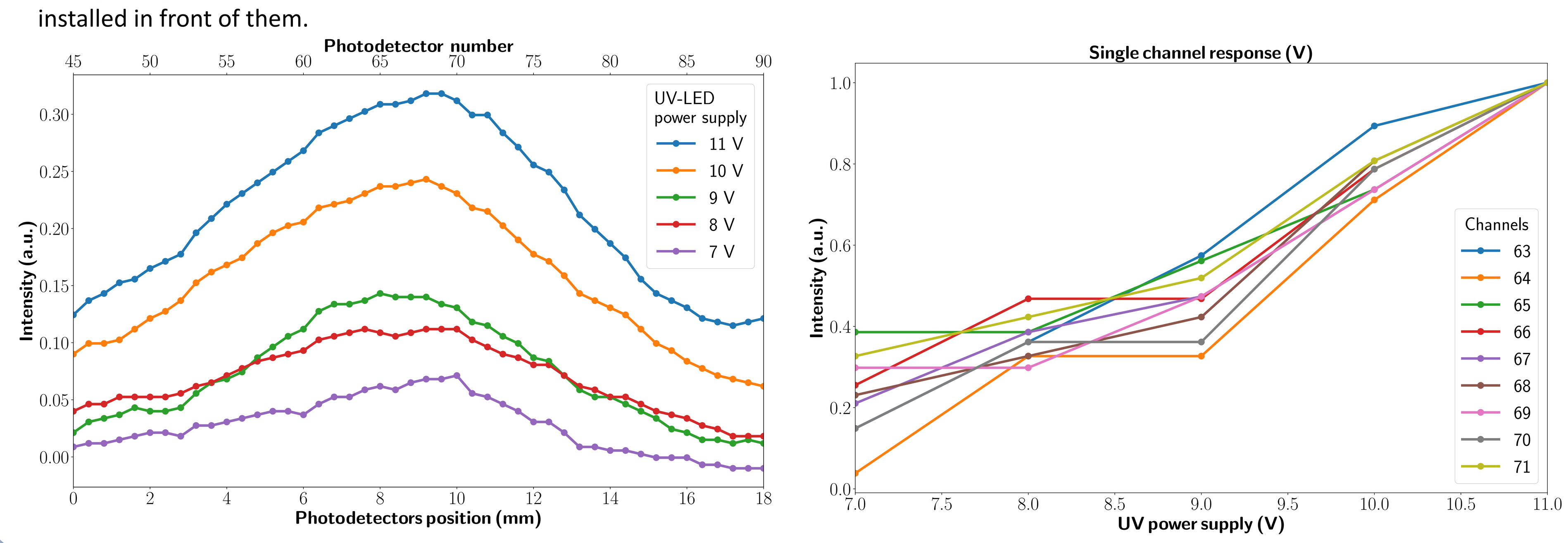


Fig. 6 Light coming out of the channel segments due to the wavelength shifting e waveguiding. The PD array is perpendicularly installed in front of them.



- Inhomogeneities in the response can be due to a different filling of the channels and the alignment between photodetectors.



Ongoing activity

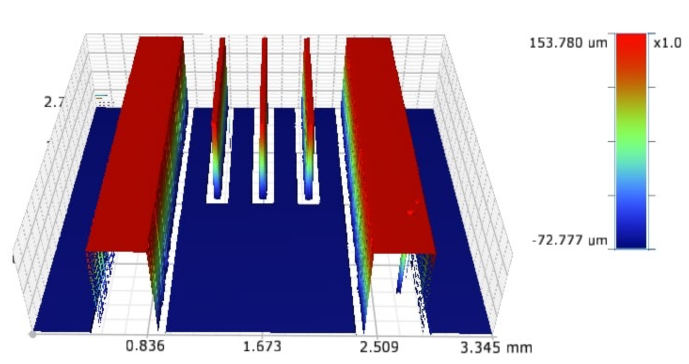


Fig. 7 Image of a PDMS mold taken by an optical profilometer.

- Tests on higher resolution devices (pitch 200um).
- Transition from a device containing a scintillating liquid to a scintillating device.
  - Advantages: no microfluidics issues, improved detectors robustness and easier assembly.
  - **Fabrication process:**

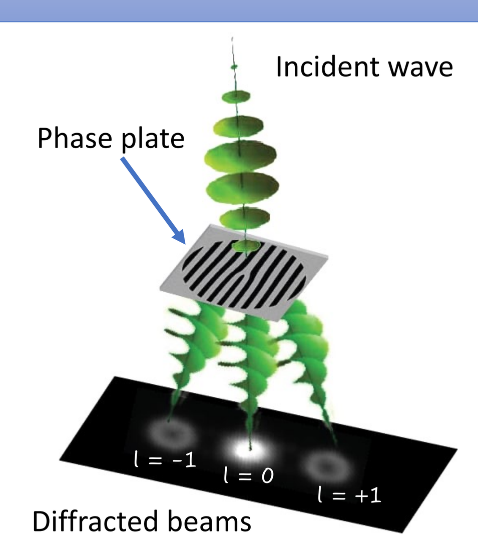
    Silicon Master → PDMS mould → Resin based device demoulding

  - Possibility to 3D print the resin

Main areas of interest

1. Beam profiler for a proton-therapy accelerator (AVO-ADAM)
   - Active area 30 mm x 30 mm, two orthogonal planes, channel width 50÷100 um, pitch 100÷200 um
2. Proton vortex beams detection
   - Active area 5 mm x 5 mm, two orthogonal planes, channel width 2÷5 um

- UHV compatible (1e-7 mbar)
- Minimized thickness



References

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[4] NEUTRON/GAMMA PSD EJ-309 liquid scintillator, ELJEN TECHNOLOGY, https://eljentechnology.com/products/liquid-scintillators/ej-301-ej-309.