Status of the Fluorescence Profile Monitor for the CERN e-Lens

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Outline

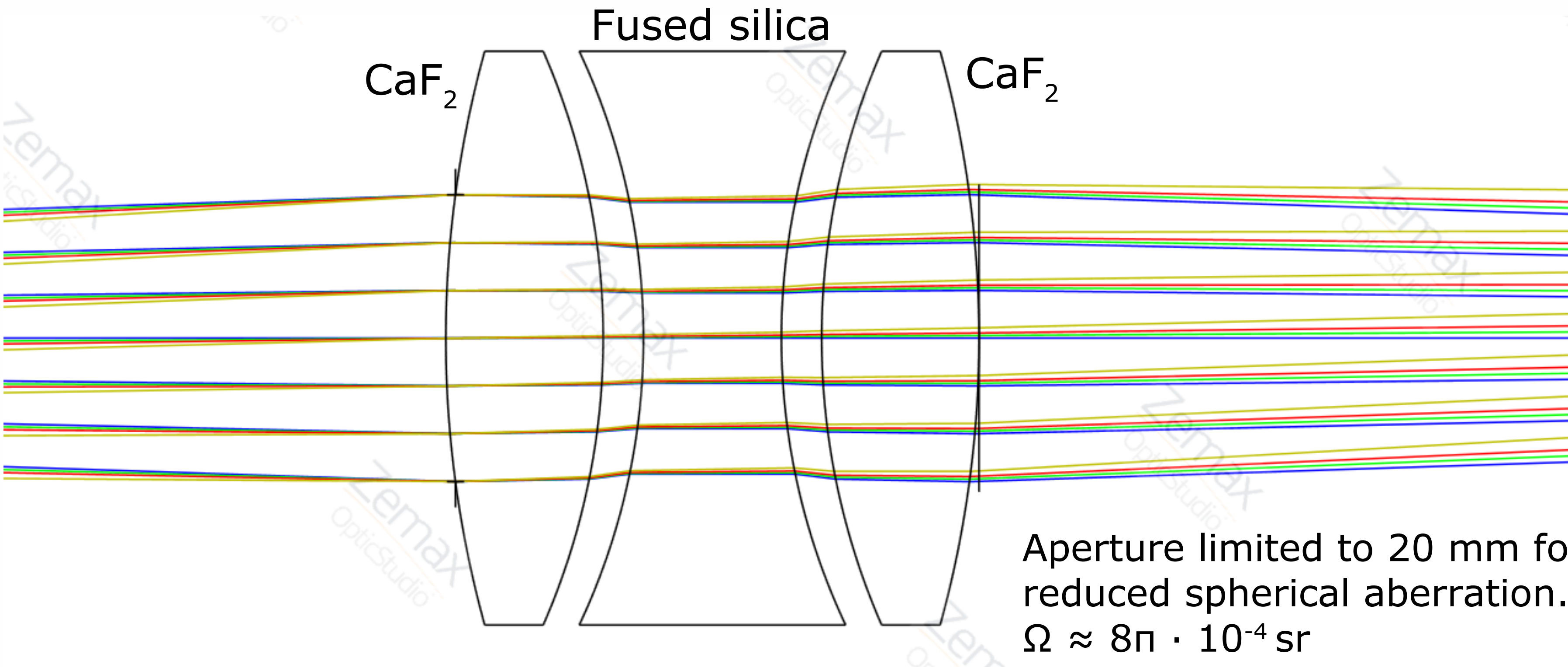
- Optics
- Image intensifier and camera
- Optomechanics
- Test setup and first results at the Cockcroft Institute
- Conclusions and outlook

Optics: present requirements

- Good transmission in the near UV, at least in the region 300 to 400 nm
- Good resolution, well corrected geometrical and chromatic aberrations
- A magnification of about 1 (absolute value) due to the relatively low resolution of the double MCP stack of at most 20 lp/mm
- Relatively large working distance to allow the placement of the detector system at d > 400 mm from the beam axis
- Large acceptance, a solid angle of about $4\pi \cdot 10^{-4}$ sr desirable
- Total depth of field (DOF) up to 15 mm with reasonable blur; can be relaxed if an appropriate setup geometry is used: camera looking perpendicular to the curtain plane or application of the Scheimpflug principle

Optics: commercially available lens (part 1)

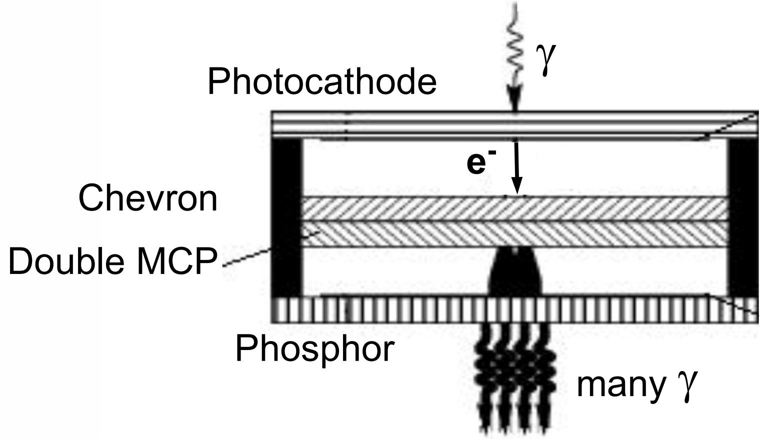
Optimized for 1:-1 imaging
Focal length (EFL): 160 mm
Maximum aperture: 40 mm
Mount diameter: 50 mm
Mount length: 54 mm
Thread: M48x1



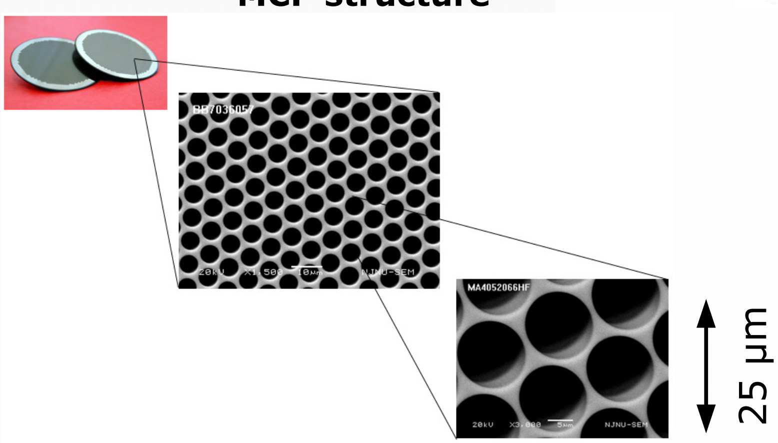
Aperture limited to 20 mm for reduced spherical aberration.
$\Omega \approx 8\pi \cdot 10^{-4}$ sr

Image intensifier working principle

MCP based amplification module



MCP structure



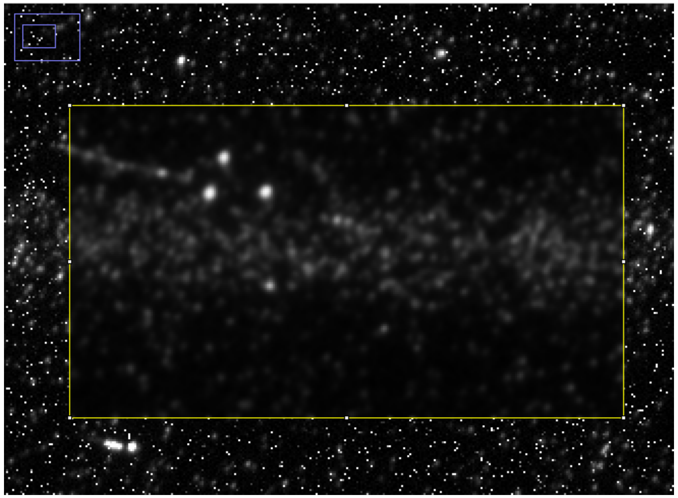
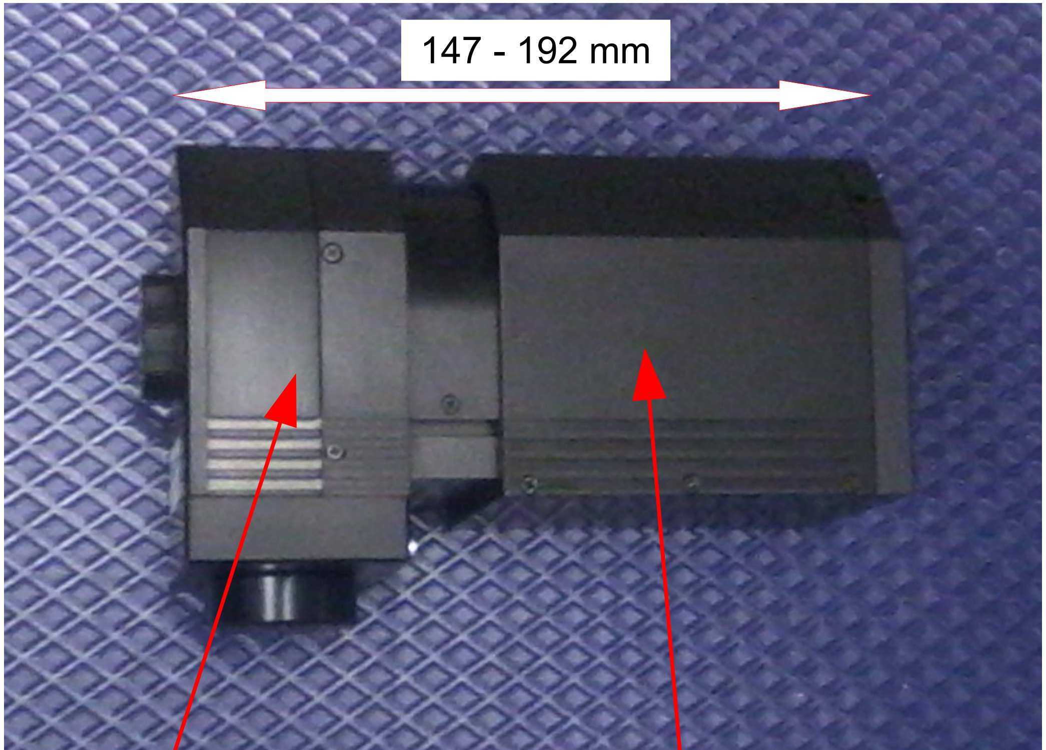


Image from $5{\cdot}10^8$, 300 MeV/u $^{238}U^{73+}$ ions in N_2, p= $5{\cdot}10^{-3}$ mbar.

The ProxiKit PKS 2581 TZ-V 25 µs

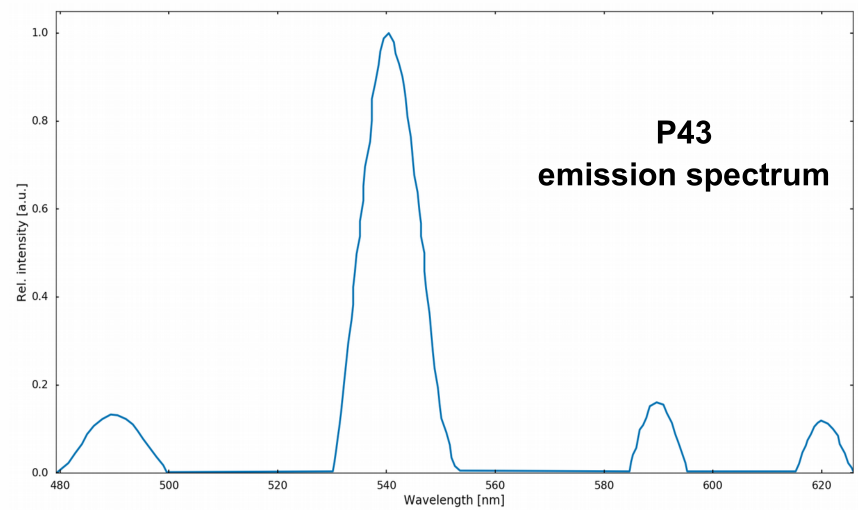


Double MCP based image intensifier and associated electronics modules

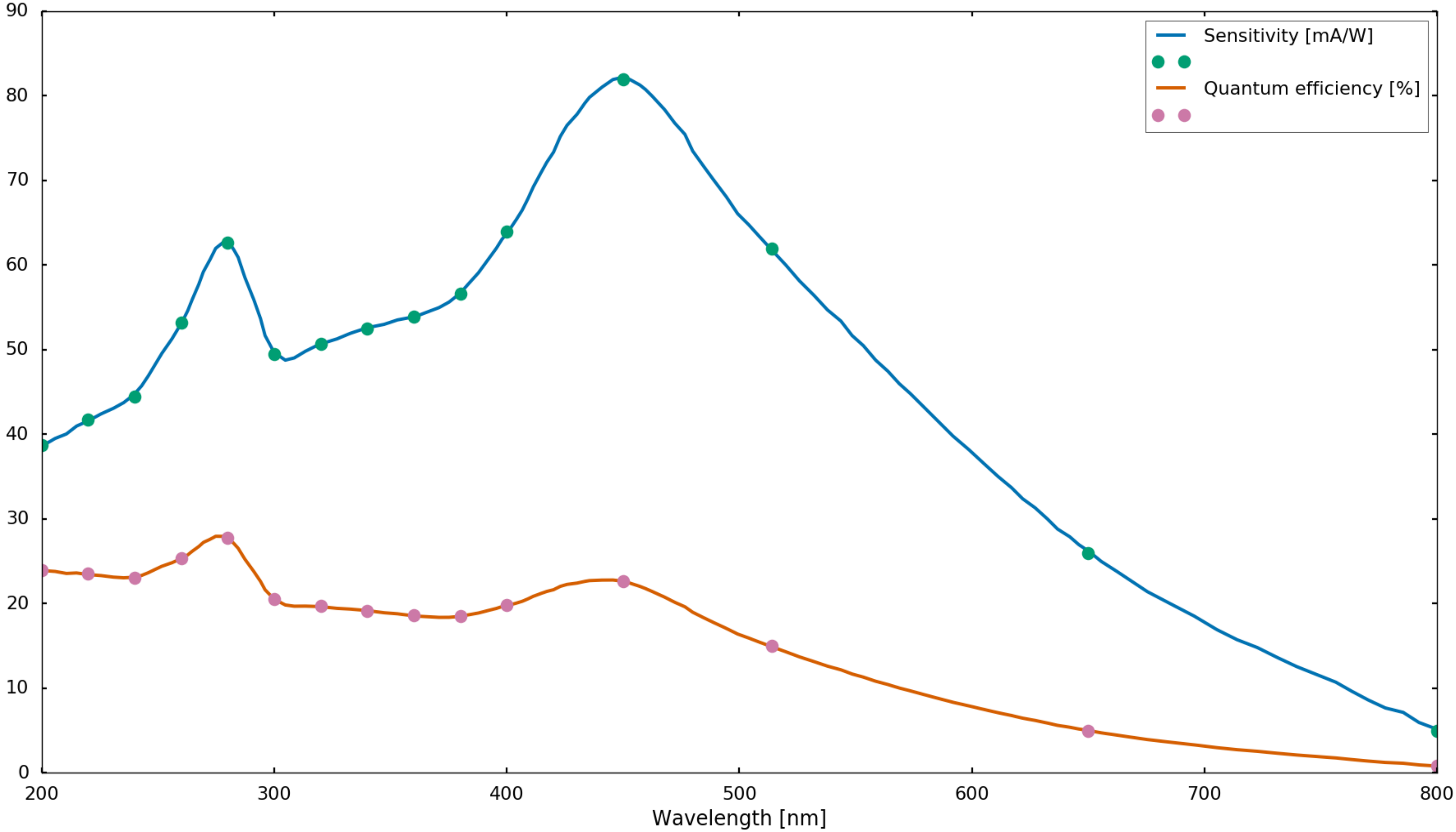
Relay optics module to image the phosphor screen onto the camera chip

Features:

– UV enhanced S20 photo-cathode
– P43 phosphor screen
– TTL gate: 25 µs to ∞, f_{max} = 1 kHz
– Flexible, user serviceable relay optics based on a Schneider Componon 12 lens offering many image ratios, e.g. 18:11 & 25:11
– Any camera with C-mount mechanics or adaptable to it can be used, as long as the detector is sensitive in the visible wavelength range as emitted by the P43



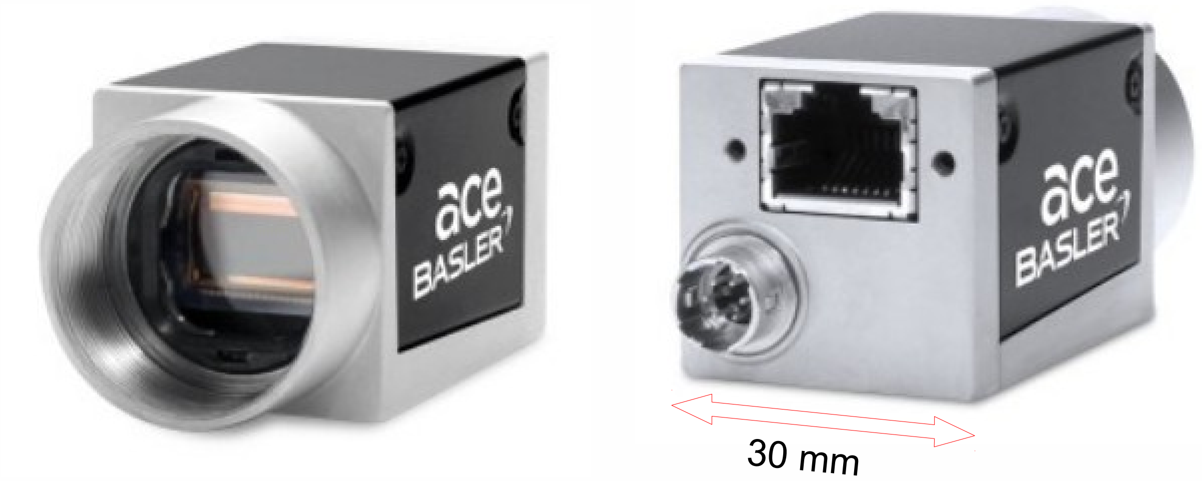
UV enhanced S20 spectral response



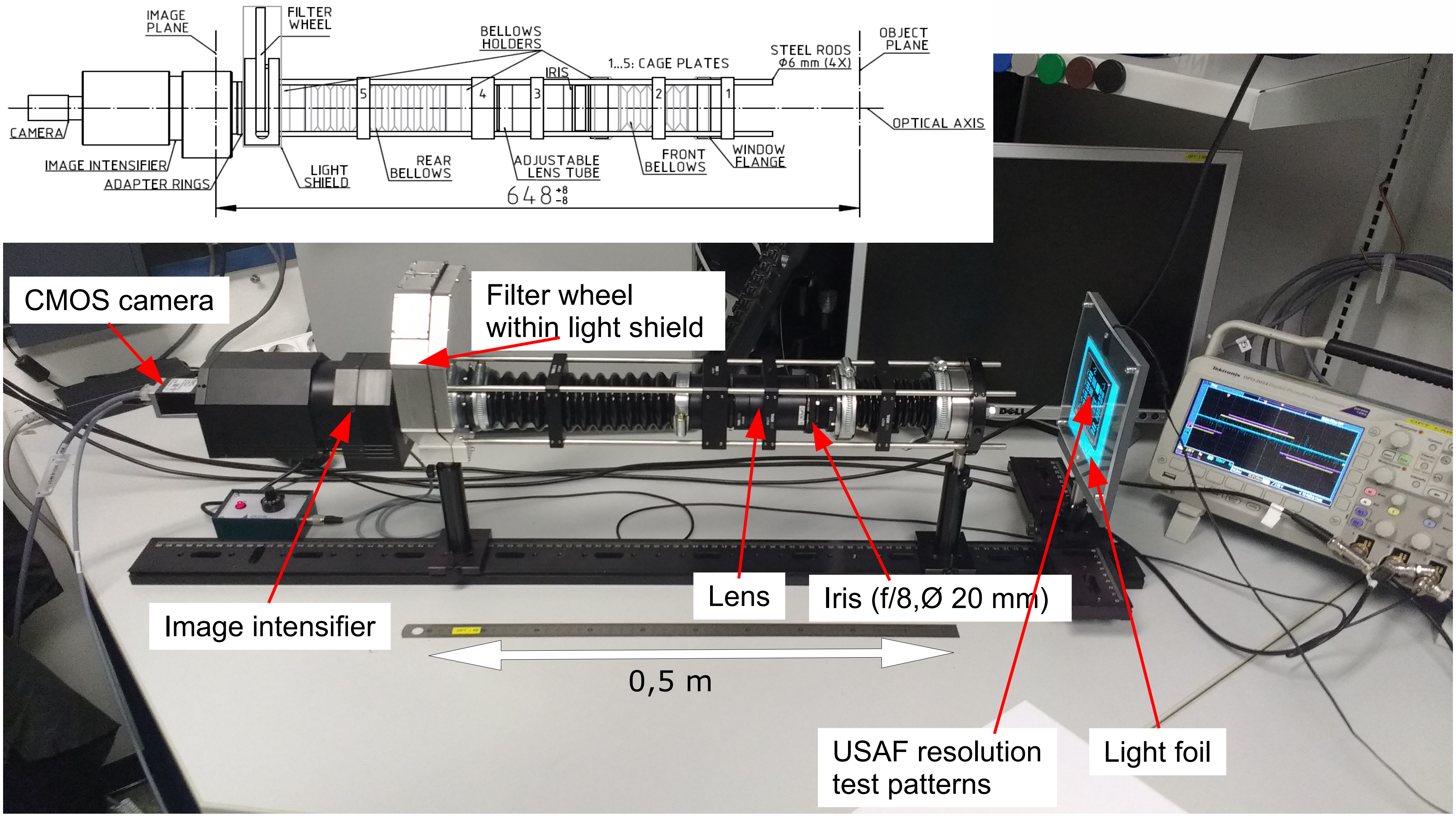
Based on data delivered by the manufacturer

The acA1920-40gm CMOS camera

Seller/ Manufacturer	Sensor	Resolution	Video Output	Exposure time	Trigger	I/O	Power (lowest voltage)
Rauscher/ Basler	Sony 1/1.2" IMX249, CMOS, 5,86x5,86 µm², Global Shutter	1920x1200	Mono 8bit, 12bit, 12bit packed	34 µs @ 8bit/ 40 µs @ 12bit – 10 s or trigger width	*Hardware Trigger:* Pulse-Edge, Pulse-Width *Trigger Modes:* Trigger Width, Sequence	1x ISO IN 1x ISO OUT 1x GP IN/OUT	PoE (36V)/ 12V DC via 6-Pin Hirose



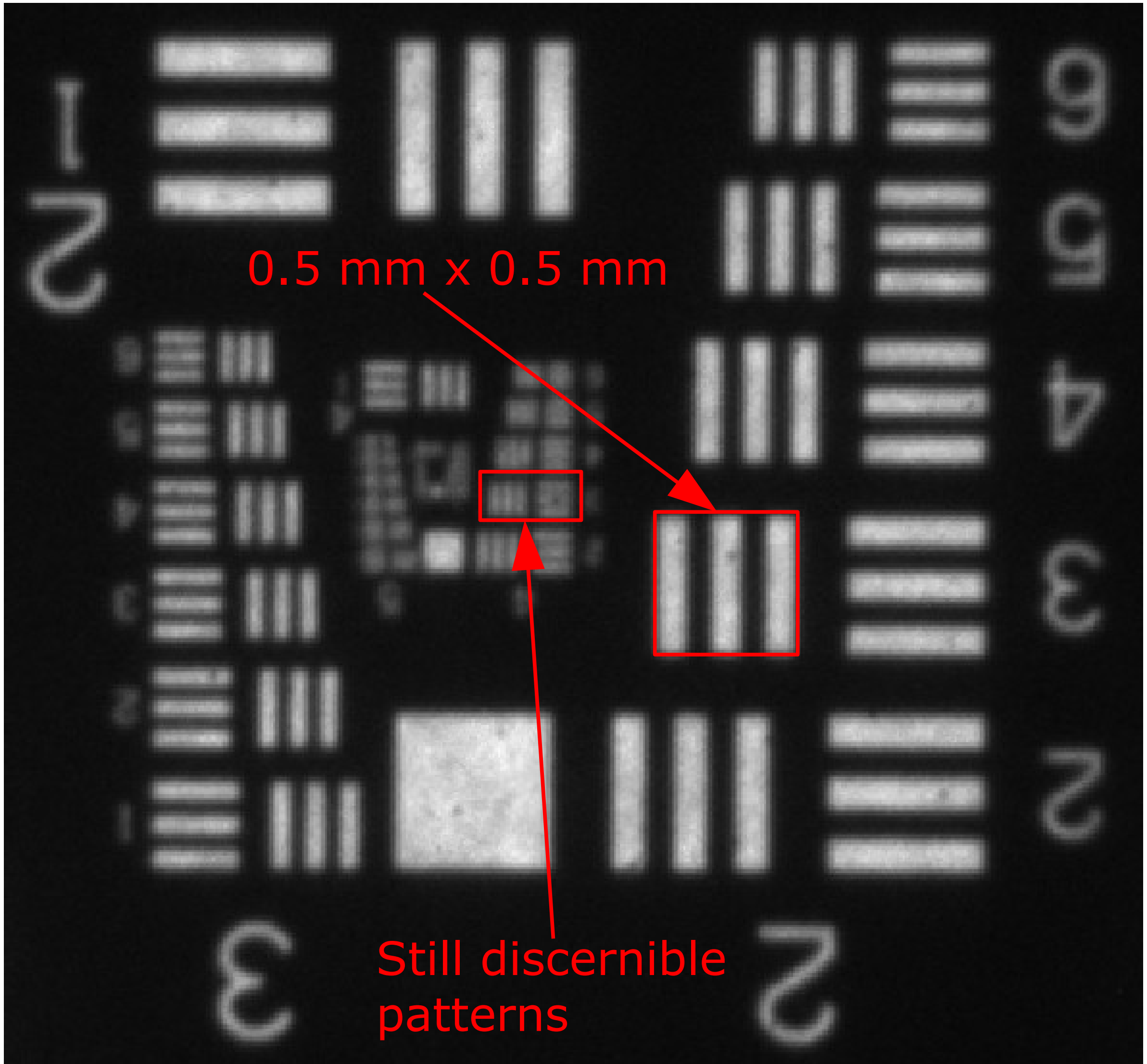
Optomechanics



NOTE: Not all parts are yet available.

Acknowledgements: C. Andre for her help during setup preparation.

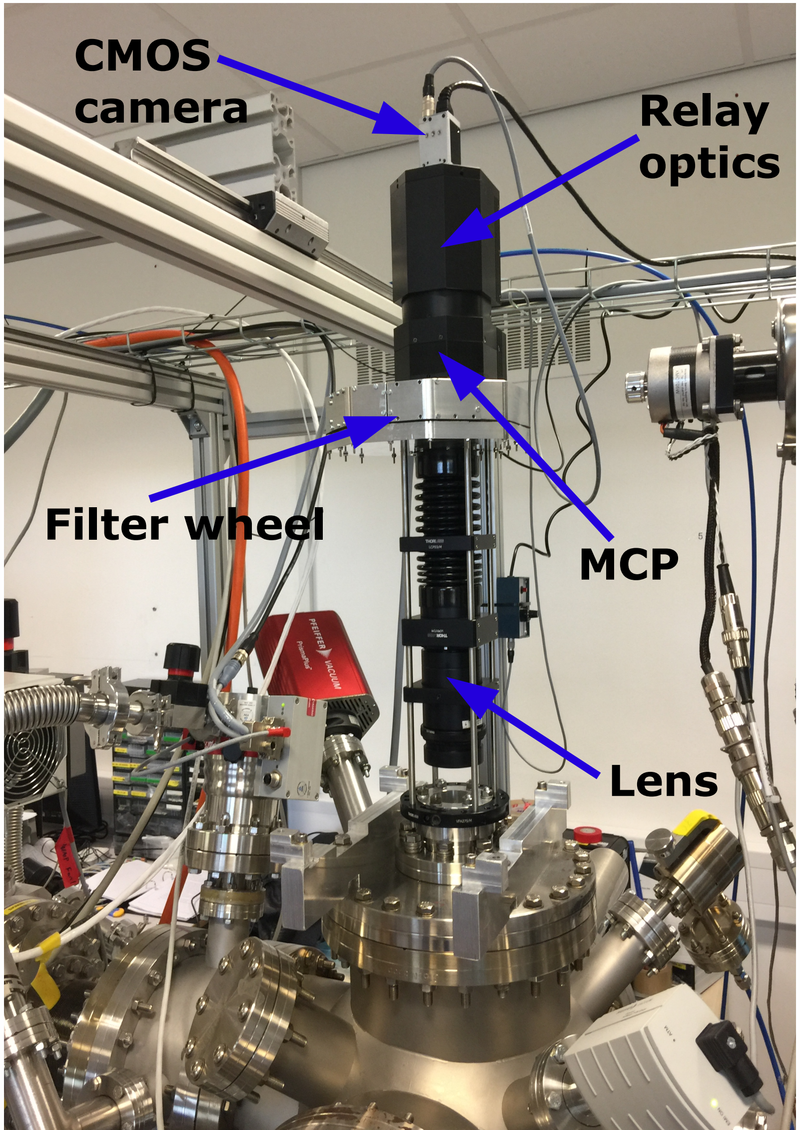
Test image (central part)



Results:
- Resolution up to 20 lp/mm
- Magnification @ MCP:
  1.2 ± 0.1

Note: The DOF has been estimated to be 4.5 ± 0.5 mm

New BIF Monitor on present Gas Jet Setup at Cockcroft



BIF setup:

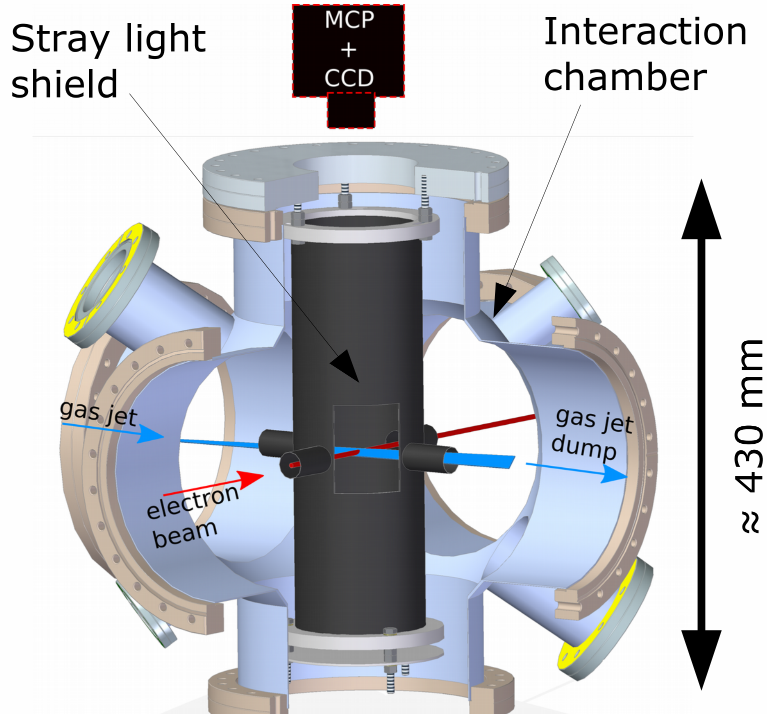
- Proxivision image intensifier with chevron double MCP
- acA1920-40gm CMOS camera
- Apochromat triplet for 1:-1 imaging, f=160 mm, F#=8, transmission band 190–2200 nm
- Filter wheel with 10 nm bandwidth filters at 337, 390 & 430 nm and a 550–600 nm filter

Gas jet curtain:

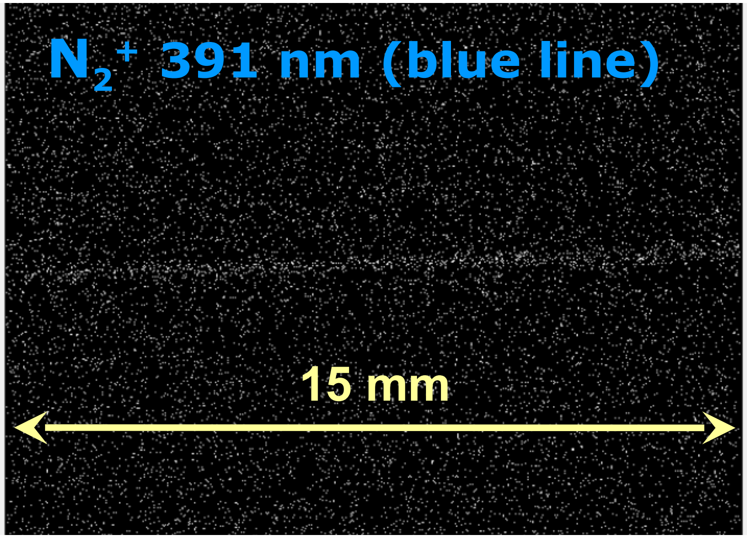
- N_2 and Ne
- Density ≈ 10^9 – 10^{10} cm^{-3}
- Thickness ≈ 3 mm
- Width ≈ 9 mm

Electron beam:

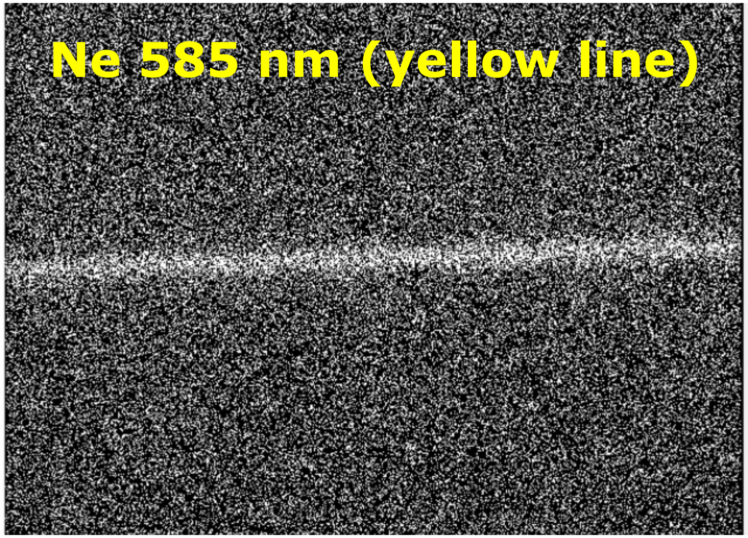
- E < 10 keV
- I < 100 μA
- Φ ≤ 1 mm



Measurements with N_2 and Ne as residual gases

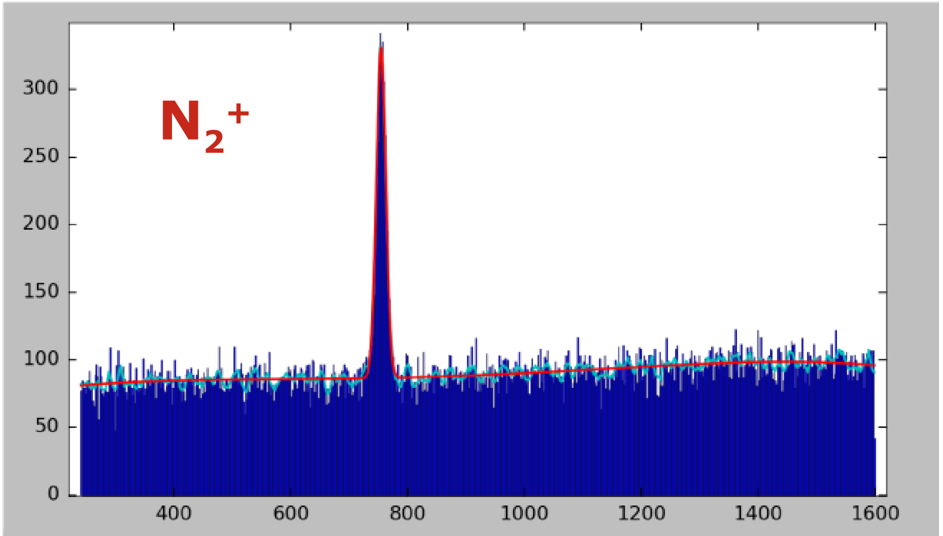


Pressure: $1.4 \cdot 10^{-7}$ mbar
e-beam: 7 keV, ≈30 μA, focused to ≈1 mm
Integration time: 160 s
Filter @390 nm, 10 nm FWHM
Emitter: N_2^+ @ 391.4 nm
Scale: 45 pixels/mm

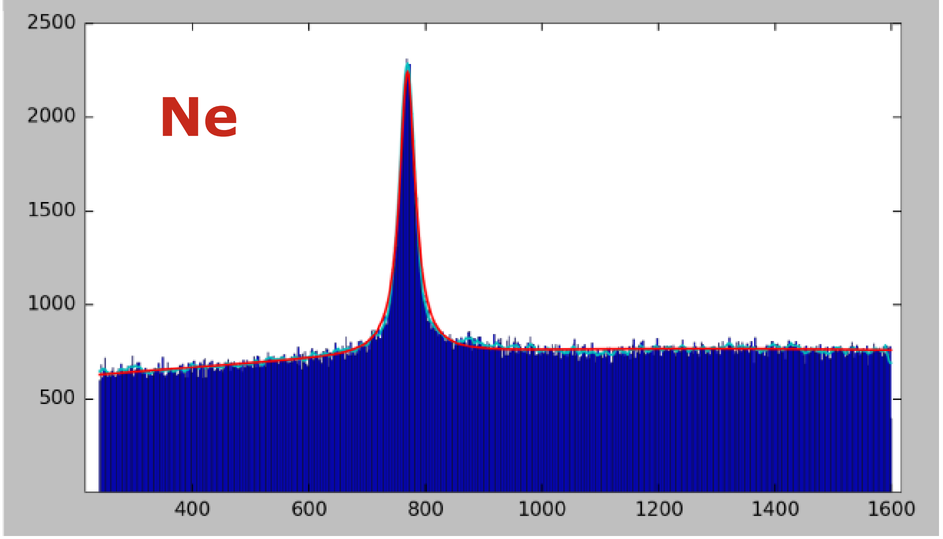


Pressure: $4 \cdot 10^{-5}$ mbar
e-beam: 7 keV, ≈30 μA, focused to ≈1 mm
Integration time: 400 s
Filter 550-600 nm, flat top
Emitter: Ne @ 585.4 nm

1D Histograms after Integration along Beam Axis



Width: FWHM = 0.42 mm
Signal strength:
N_γ measured: 2500
N_γ estimate: 2000
Within expected uncertainties!
Signal-background ratio: As expected!
(pressure is main error)



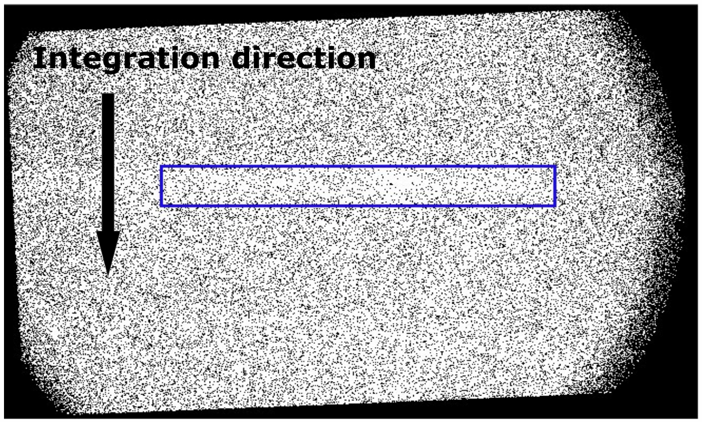
Width: FWHM = 0.75 mm
Signal strength:
N_γ measured: 40000
N_γ estimate: 12700
Within expected uncertainties!
Signal-background ratio: As expected!
(pressure is main error)

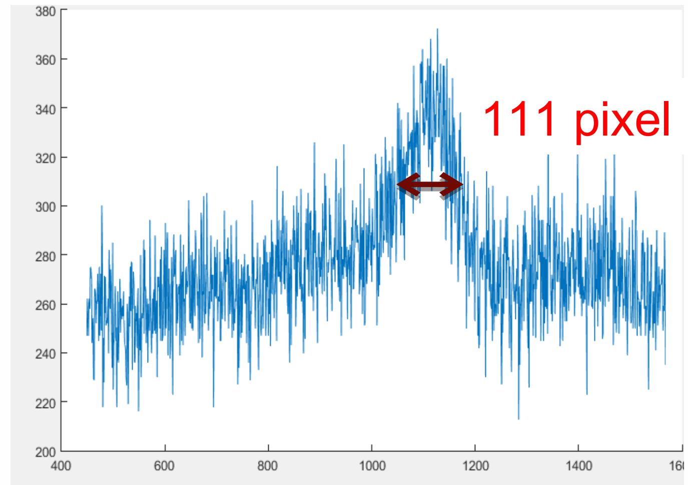
Fit of peak: Voigt profile
Background: 4th oder polynomial
Remark: Voigt profile is a convolution of a Gaussian and a Lorentz-curve

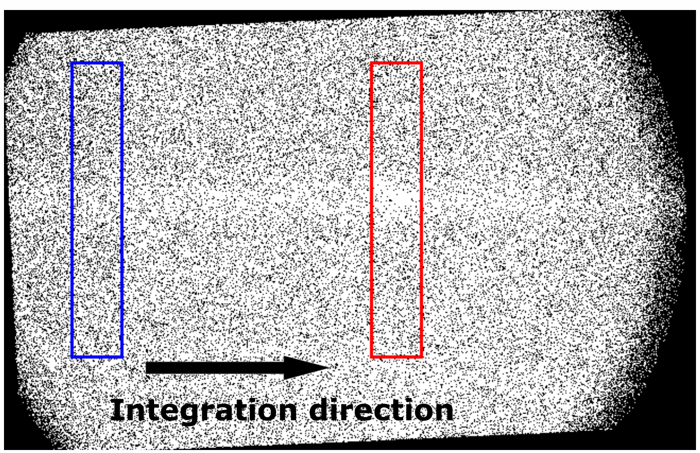
Measurement with N_2 Gas Jet Curtain

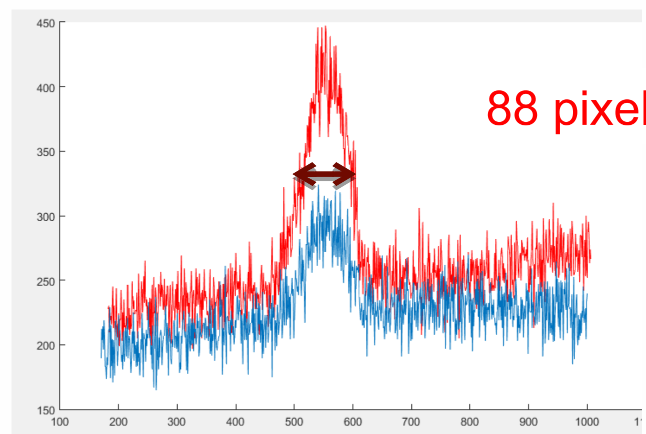
Parameters: **electron energy:** 5 keV, **beam current:** ≈30 μA, **pressure:** ≈$6 \cdot 10^{-8}$ mbar, **integration time:** 4000 s

Overlap between electron beam and gas jet curtain detected!

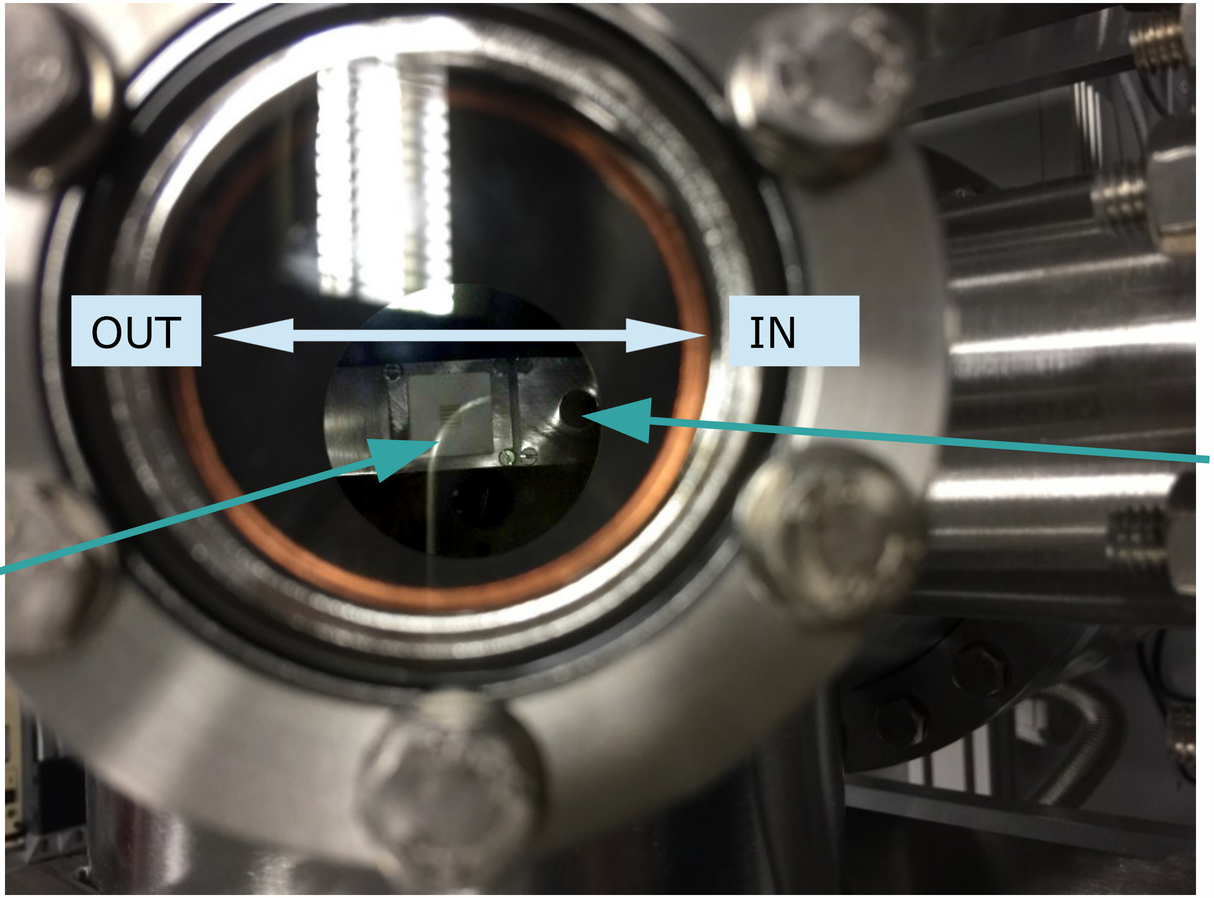








Adjustment target and scintillator



Adjustment target: gold stripes deposited on Al_2O_3 substrate.

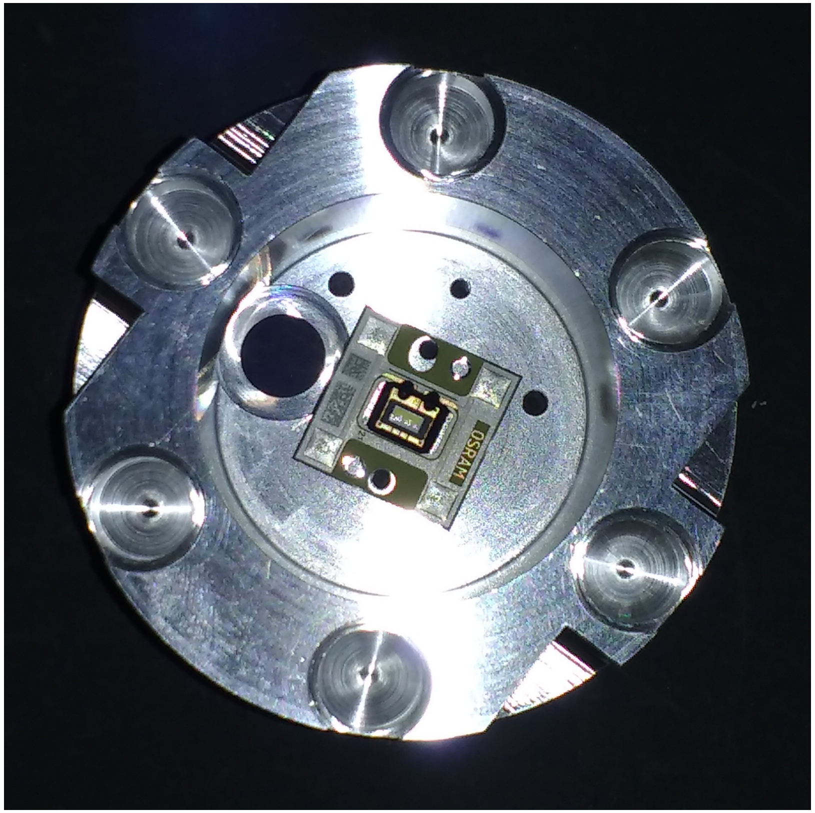
Scintillator: CRY-18 by CRYTUR with strong emission around 400 nm

Remark: Proved to be extremely fragile!

The adjustment target and scintillator assembly mounted on the new gas jet setup and shown through the BIF viewport

(Photo: H. Zhang)

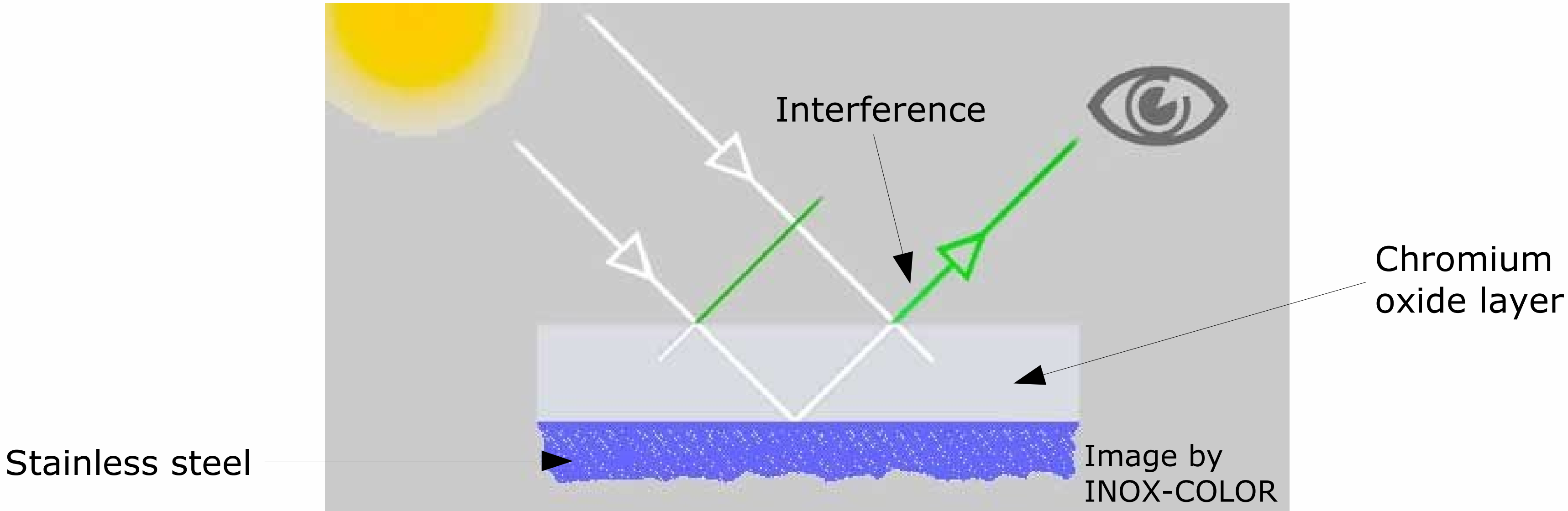
LED add-on



The LED add-on still at GSI together with the OSRAM LE-UW-U1A3-01 LED.
Electronics for driving the LED not yet ready due to missing manpower.

Interaction chamber blackening

According to the experience at GSI interaction chamber blackening is a must because of the low signal level.



At GSI we had good experience with the company INOX-COLOR.

No dies are involved! They realize a very thin and transparent chromium oxide layer at the surface. This can withstand temperatures up to 200°C for long times and higher ones (up to approx. 300°C) for short times. It is not very resistant against abrasion, but it can sustain mechanical deformation of the substrate, e.g. bending. The final effect (blackening) is obtained due to interference.

Remark: If necessary one can additionally use some graphite spray for certain regions of reduced size.

Making the BIF setup LHC compatible

- Is a radiation shield necessary?
  - particles with long interaction paths within the MCP (i.e. moving almost parallel to the photocathode's surface) may lead to useless images,
  - lens materials may lose their transparency,
  - other camera types (e.g. emCCD) may be more sensitive to radiation.

- Is a magnetic shield necessary?

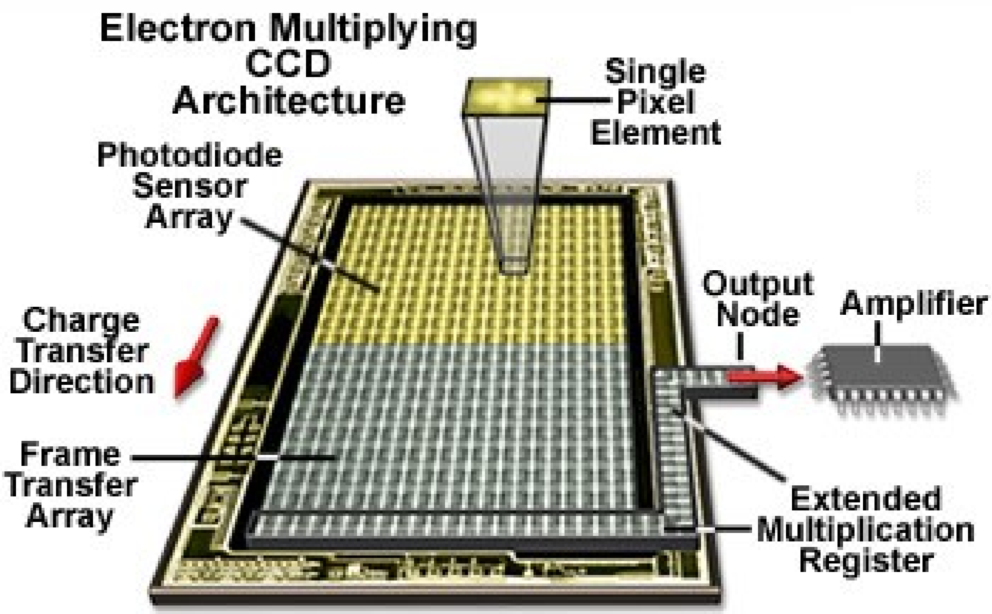
- Another camera type for increased detection efficiency at long wavelengths (e.g. of the Ne 584.5 nm line)?

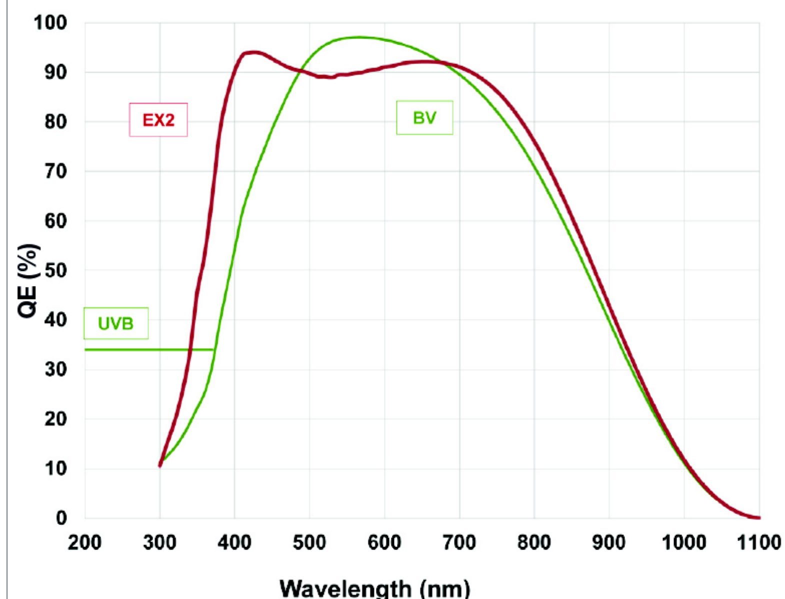
- Modify geometry to allow for a short depth of field and thus increase acceptance of the lens?

- Optimize the lens? The present lens allows for measurements within a broad spectral range and relatively high magnifications. However, depending on the final spectral range of interest and the size and resolution of the future detector, a more appropriate lens may be chosen.

emCCD cameras as a possible alternative to MCP

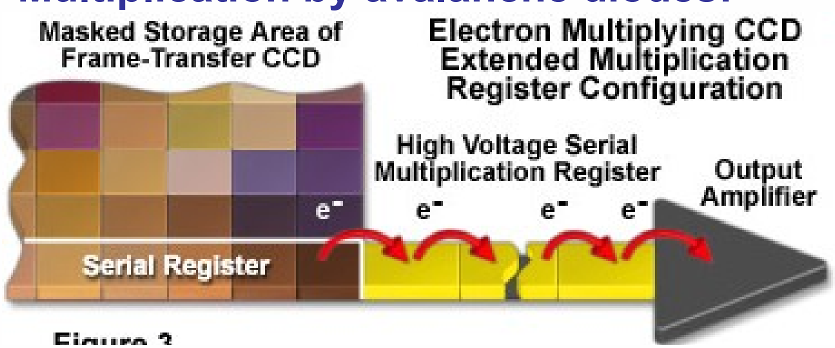
Principle of electron multiplication CCD:





QE of an iXon Ultra 897 emCCD made by Andor

Multiplication by avalanche diodes:



Parameters of an iXon Ultra 897 (16bit)

- Pixel: 512x512, size 16x16 μm^2 , -100 °C
- Maximum amplification: x1000
- Readout noise: < 1 e$^-$ per pixel

Remarks: Higher noise due to amplification mechanism, more expensive, if damaged has to be completely replaced, radiation hardness unknown.

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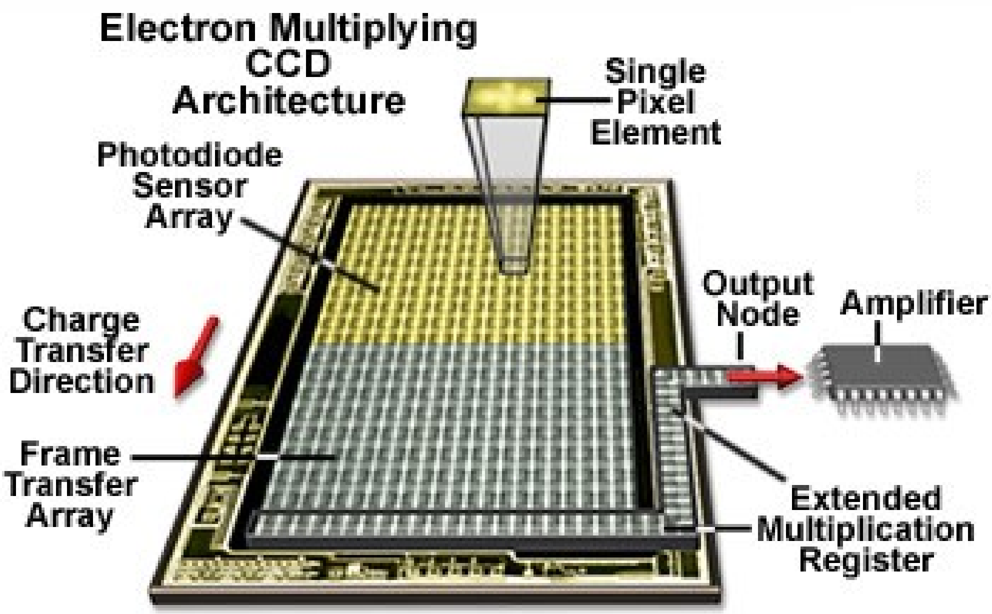
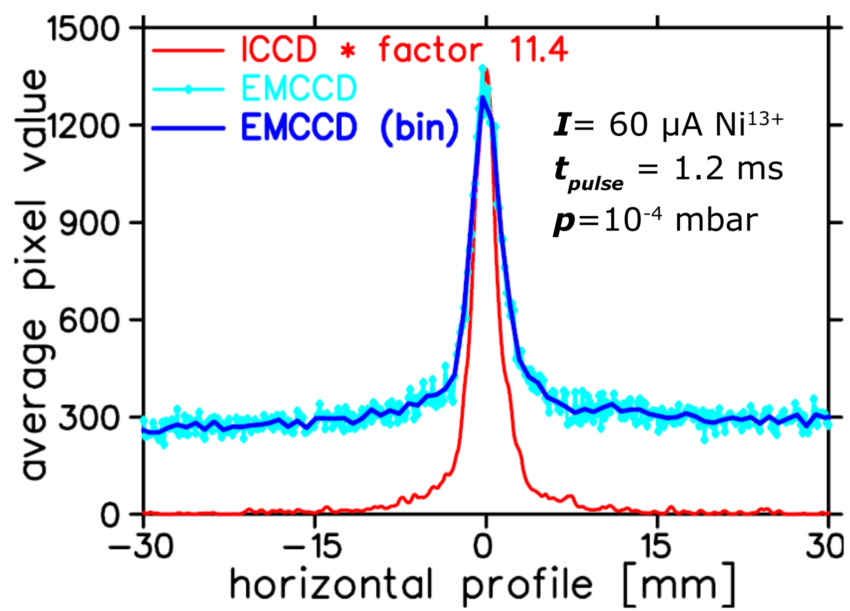
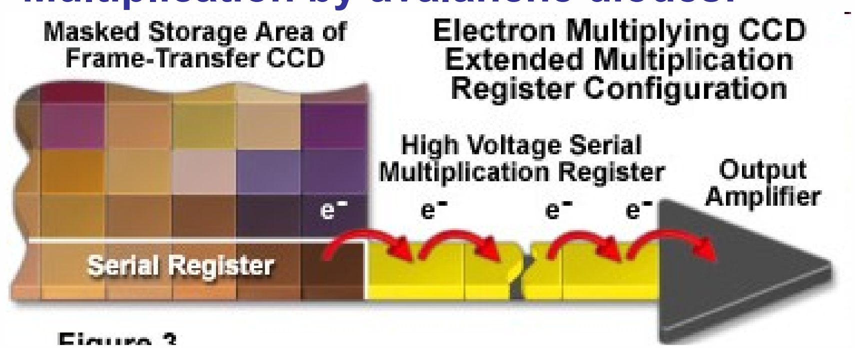




emCCD camera test measurements at GSI

Multiplication by avalanche diodes:



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Conclusions and outlook

- The new MCP based BIF setup has been realized, successfully tested offline and commissioned at the existing gas jet curtain setup
- A new adjustment target has been manufactured and installed on the future gas jet curtain setup at Cockcroft, there are issues with the scintillators which are much more fragile than expected
- LED and mechanical add-on for adjustment target illumination are available, electronics for driving the LED still under development
- Mechanical BIF setup support manufacturing ongoing
- Detailed comparison between Neon, Nitrogen and Argon still pending, should be performed after the installation of the new electron gun at Cockcroft
- Quasi-simultaneous measurement of electron beam current and profile at Cockcroft