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DEVELOPMENT OF A PEPPER POT EMITTANCE MEASUREMENT DEVICE FOR THE HIT-LEBT

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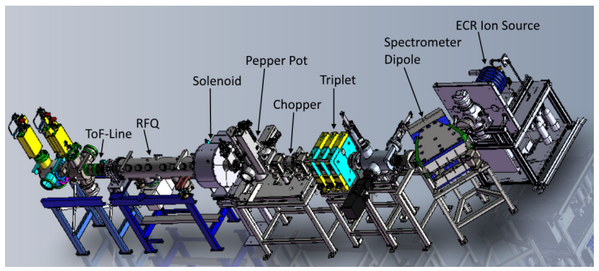
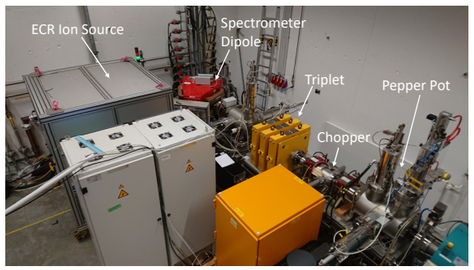
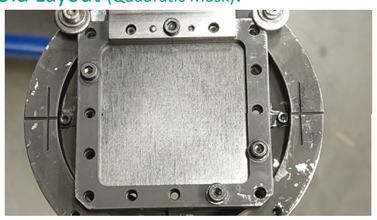
Abstract
The Heidelberg Ion Beam Therapy Centre (HIT) is a synchrotron based medical accelerator facility for the treatment of cancer patients with ions. Since the first treatment in November 2009 about 7000 patients have been irradiated with protons or carbon ions and, since July 2021, also with helium ions. In 2010 HIT started the operation of a test bench with a setup comparable to the LEBT at the accelerator. Since 2013 the test bench serves as a common low energy beamline of Siemens Healthcare and HIT with components from both partners. In parallel to ion source and RFQ research and development we have experimented with our proprietary pepper pot device. We plan to install the final version of the pepper pot into the LEBT section and use the measured beam distributions for the design of a new RFQ. With the recent redesign of the mask-target assembly we have increased the active area of the device and generated a possibility for an accurate pixel calibration by a specialised calibration mask. Our tool PePE (Pepper Pot Emittance Evaluation) offers different approaches for the reconstruction of the 4D emittance parameters from the raw image. The evaluation process was validated by a pepper pot image generated from a simulated beam with known properties.

HIT Test Bench


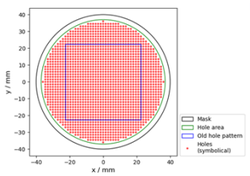


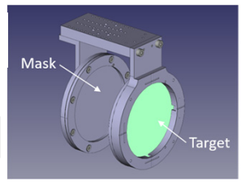
Pepper Pot Hardware

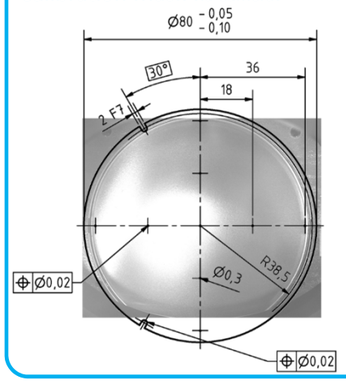
Mask		Screen	
material	tungsten	material	quartz glass
thickness	100 µm	supplier	Aachener Quarzglas-Technologie Heinrich
hole spacing	1.5 mm	product	Herasil 3
hole diameter	100 µm	thickness	200 µm

Old Layout (Quadratic Mask):


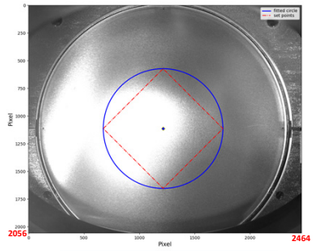
New Layout (Round Mask):



Pixel Calibration
Calibration Mask via Camera:


Circle Fit:
- Four hole approximation of manually marked holes



Calibration in this example:
30.03 pixel per mm

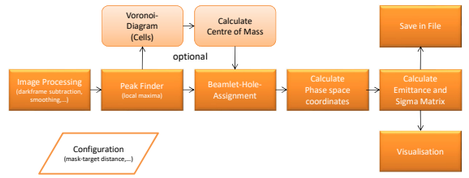
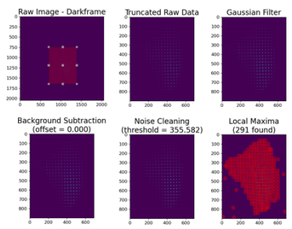
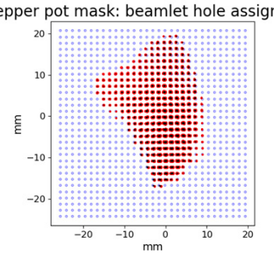
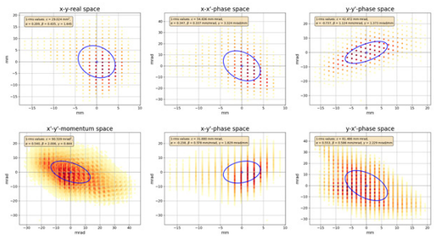
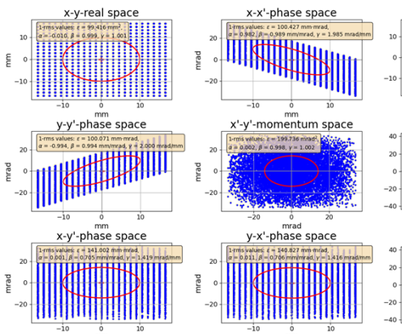
Measurement Sequence
Evaluation Steps:


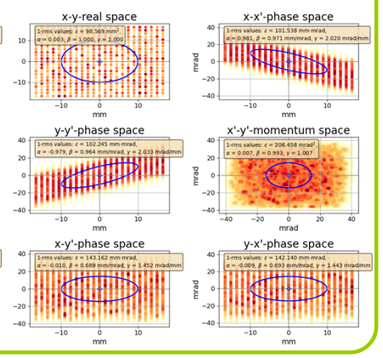
Image Processing:


Pepper pot mask: beamlet hole assignment


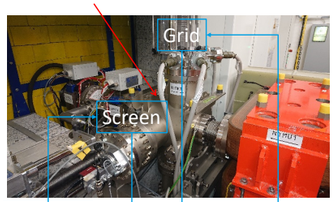
Emittance Result of 126 µA C-Beam:


Validation Beam
- Particle generation:
  in the presented case 2.5 millions uniformly distributed particles correlated in the horizontal (convergent) and vertical phase space (divergent), uncorrelated in the mixed phase spaces
- Masking:
  particles not passing the mask holes are filtered out
- Drift:
  particle drift from the mask to the screen (here 15 mm)
- Image generation:
  from a 2D histogram of the particles a tif-image is generated, which is evaluated as it was a real measurement

Masked Beam (Input):


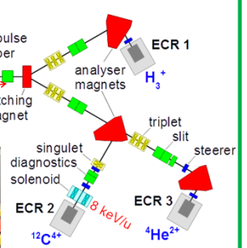
Emittance Result:


LEBT Integration
Designated place of installation



Mirror + Camera

Mask + Target



Conclusion and Outlook
At HIT, a pepper pot emittance meter was constructed which recently got a new design with a larger active area. In parallel, an evaluation tool was developed giving us the correlations of all 2D subspaces. We found a way to validate the algorithm by the generation and evaluation of an artificial pepper pot image.
In a next step we are going to repeat earlier measurements with the new mask-screen layout. The resulting particle distributions are an important ingredient for our ongoing project of designing a new RFQ with the goal of transmission optimisation.