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Accelerator Research and Innovation for European Science and Society

Summary presented at:

IBIC 2021 International Beam Instrumentation Conference

Summary on ARIES-ADA virtual Workshop on 'Materials and Engineering Technologies for Particle Accelerator Beam Diagnostic Instruments'

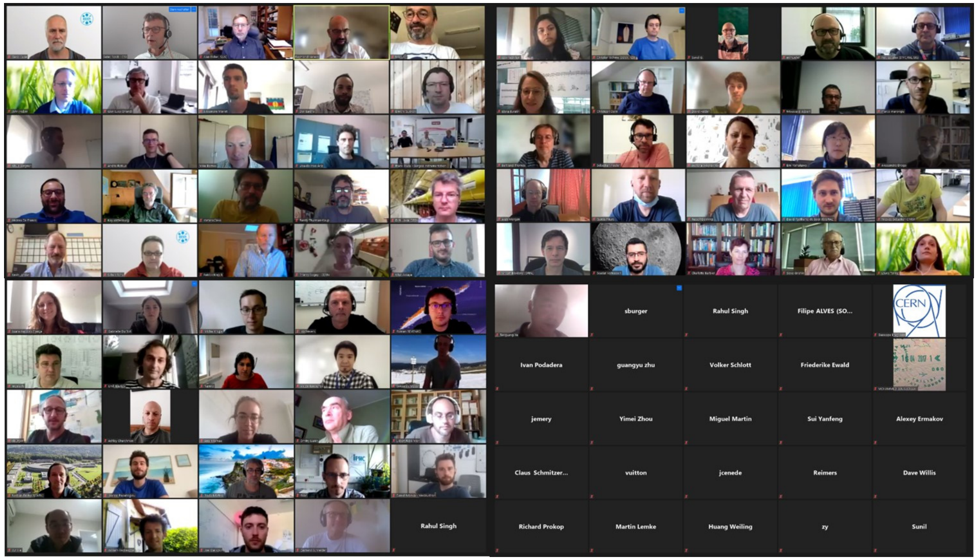
Virtual workshop June 21st to 23rd, 2021

Organized by CERN, GSI & Dep. of Engineering Science Oxford University

Program Committee: U. Iriso – ALBA, R. Veness, R. Jones – CERN, G. Kube, K. Witterburg – DESY, P. Forck – GSI, D. Eakins – University Oxford, V. Schlott – PSI

Workshop on Materials and Engineering Technologies

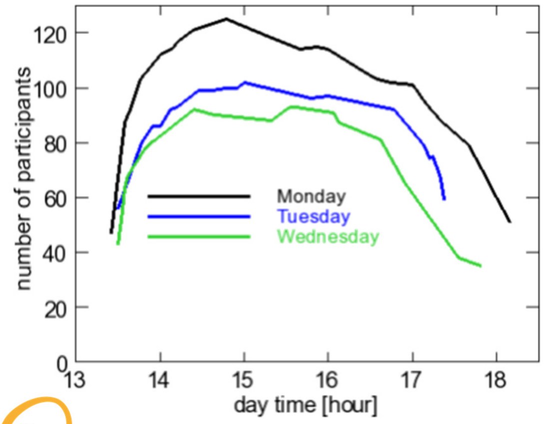
Title: ‘Materials and Engineering Technologies for Particle Accelerator Beam Instruments’



Execution of remote workshop:

- Date: June 21st to 23rd, 2021
- 205 registered participants

  15 Americans, 20 Asian, 170 Europeans
- ≈ 100 simultaneous attendees
- 3 half days, afternoon in Europe
- In total 22 talks, 25 min each
- No pre-recordings for lively atmosphere
- Break-out rooms for discussion
- Documentation at https://indico.cern.ch/event/1031708/



ARIES integrating activity:

Accelerator Research and Innovation for European Science and Society:

- 18 work-packages funded by European Union 2016-2021
- 41 institutions from 18 countries coordinated by M. Vretenar CERN

Work-package **Network ADA = Advanced Diagnostics for Accelerators:**

→ ***special topic*** workshops and exchange of personnel

- 8 in-person workshops as face-to-face event, 30-85 participants
- 3 remote workshops, up to 200 participants
- Documentation at https://aries.web.cern.ch/wp8

Workshop on Materials and Engineering Technologies

Title: ‘Materials and Engineering Technologies for Particle Accelerator Beam Instruments’

$\rightarrow$ **Novel applications for accelerator beam instrumentation**

The aims of the Workshop are to review:

- Novel materials and application
- Innovative production methods
- Improved vacuum components
- Information concerning experiences
- Intensify collaborations institutes and industry

Acknowledgement to all speakers and attendees for very valuable contributions

This talk:

- **All talks** described important developments and results
- Presentation of few highlights related to **personal** view
- References: See workshop web-site
  https://indico.cern.ch/event/1031708/ & IBIC proceedings

Carbon Nanotubes for fast rotating Wire Scanner

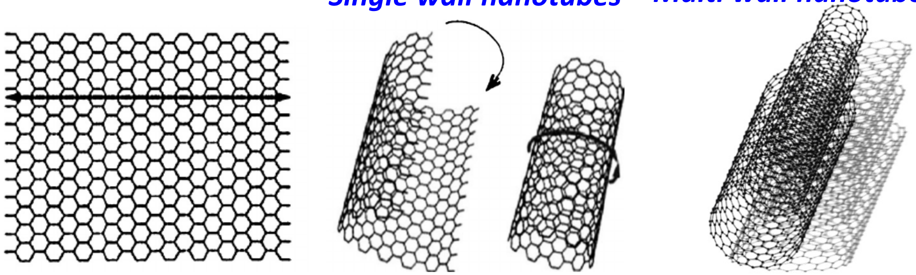
Talk by William Andreazza and Alexandre Mariet on behalf of CERN

Requirements: High speed 20 m/s & acc. 15000 rad/s^2
⇒ mechanical stiffness
⇒ light (low-Z) material
⇒ high temperature tolerance

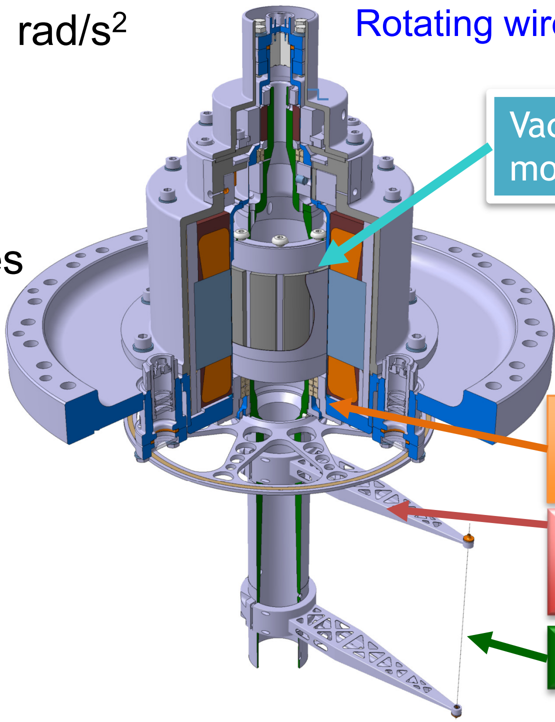
New techniques for wire: Carbon nanotube wires

Result: CNT wires successfully tested

Single wall nanotubes *Multi wall nanotubes*



Rotating wire scanner at CERN



Mechanical properties of carbon materials

Material	ρ [$g.cm^{-3}$] Density	σ_{max} [GPa] Tensile strength	E [GPa] Young modulus
CNT (SWNT)[1]	0,02 - 4	up to 150	up to 1e3
Carbon fiber [2]	1,7 - 2,5	0.6 - 4.5	60 - 500
CNT wire [3]	1.1 - 2.1	0.2 - 3.3	20 - 100

Carbon Nanotubes for Stray Light suppression by black Coating

Talk by Ben Jensen on behalf of company NanoSystem in collaboration with CERN

Requirement: In-vacuum suppression of stray light for optical monitors

Method: Spray coating of carbon nanotubes
Post processing by backing

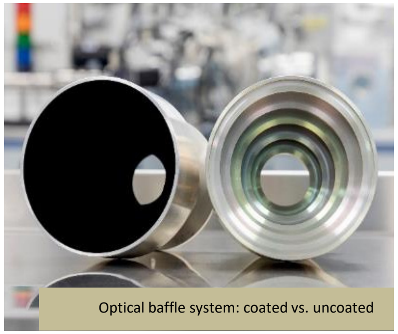
Product: 'Vantablack', several types available

Results:

- Broadband (UV to NIR) reflection below 0.5 %
- Acceptable mechanical properties
- Low vacuum outgassing
- Radiation hard

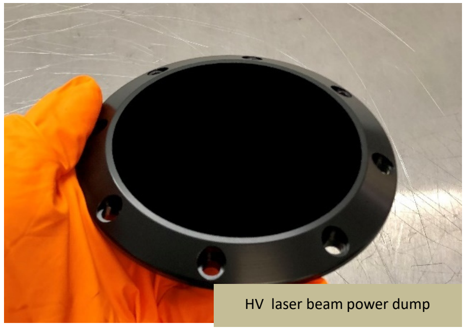
Tests at CERN performed

Production examples



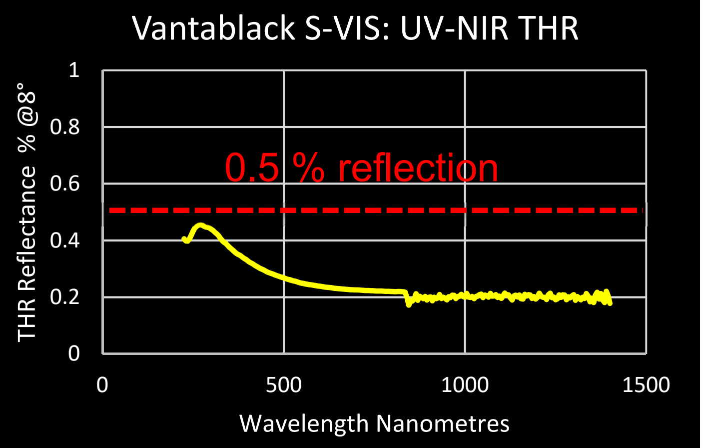
Optical baffle system: coated vs. uncoated

UHV Instrument module coated with S-VIS



HV laser beam power dump

Example: Full hemispheric reflection



Company background
in space technology

Scintillator made of Boron Nitride Nanotubes

Talk by Kavin Jordan on behalf of Jlab, collaboration with BNL, GSI & Rice University

Method: Disk made of ∅ 2- 6 nm Boron Nitride nanotubes BNNT

Advantage of BNNT:

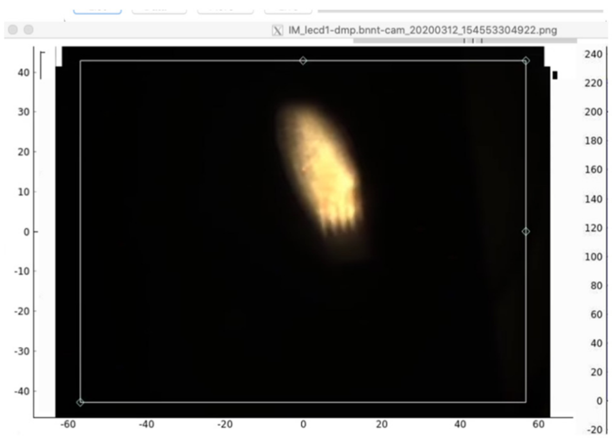
- Low density ⇒ robustness for high power beam
- Good mechanical stability, large size possible
- No blooming due to separated tubes
- Fast decay time ≈ 10 ns

Tests: Electron beam at Jlab & BNL, 1.6 MeV < E_{kin} < 7.4 GeV
Ion beam at GSI, E_{kin} = 4.8 MeV/u

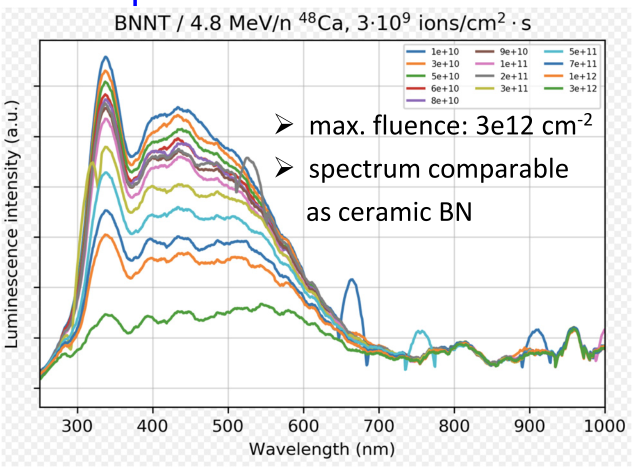
Results:

- Light yield ≈ ¼ compared to Chromox
- Radiation damage tested
  (e.g. 8 % decrease for 80 mC electrons)
- Surface modification investigated

Example: Test at BNL LEReC



Example: Test with ions at GSI



Adaptive Manufacturing: Example of fast Wire Scanner

Talk by Ana Miarnau on behalf of CERN

Adaptive Manufacturing: Manufacturing parts by adding layer upon layer of material

Examples of methods for metals: DED & EBM

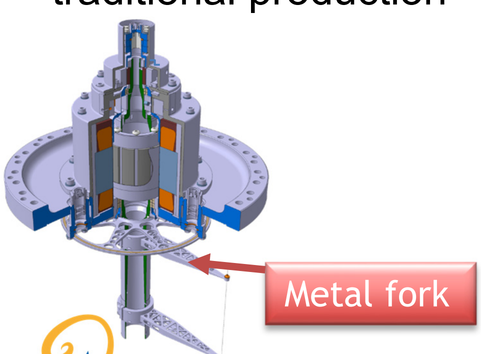
Design of wire scanner fork:

- High stiffness in two planes and
- Low inertia
- Titanium alloy Ti-6Al-4V chosen

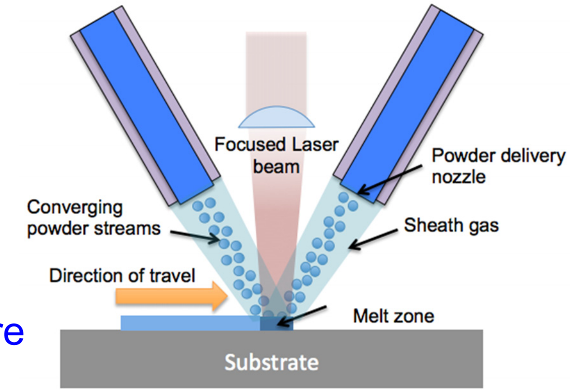
Series of 56 forks produced in 3 batches

Results:

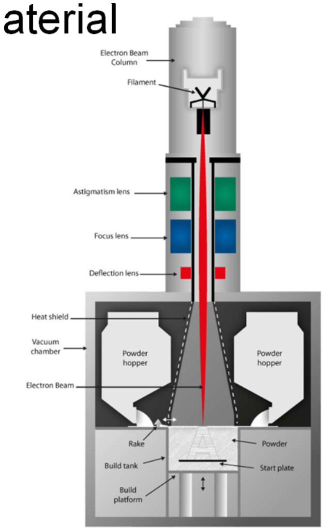
- Fully functional
- Vacuum outgassing comparable to traditional production



Example: Fork for wire scanner at CERN



Powder fed:
Direct
Energy **D**eposition



Powder bed:
Electron **B**eam
Melting

Magnetically coupled Vacuum Drives

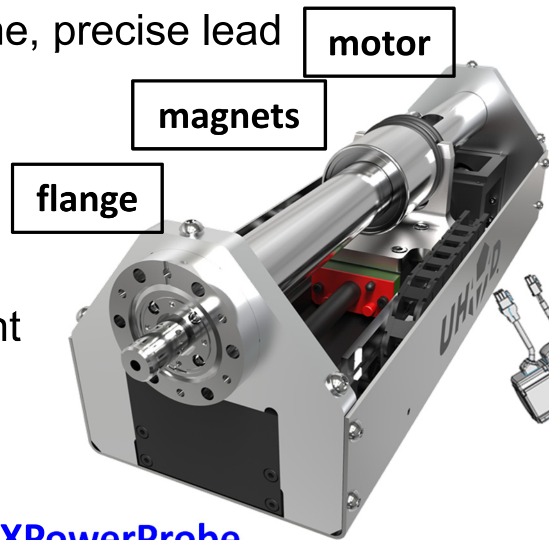
Talk by Nick Clark on behalf of company UHV-Design, collaboration with CERN, PSI

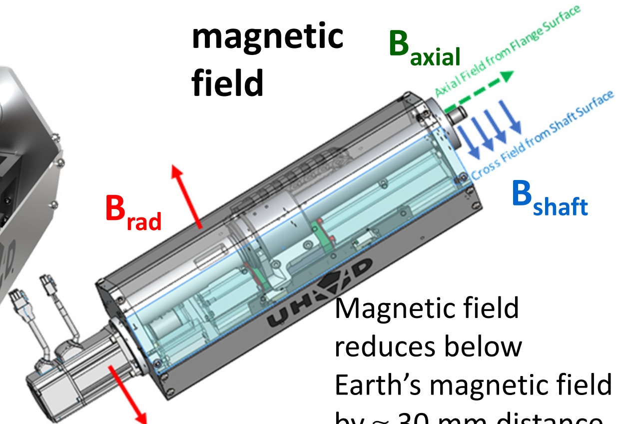
Technique: Magnetically coupled push-pull drives for UHV

Advantages: Bellow-free ⇒ long lifetime, precise lead

Achievements:

- Large magnetic coupling force
- Low residual magnetic field, e.g. 50 μT at 30 mm distance
- Metal rolling bearing without lubricant
- Very low outgassing, suited for UHV
- High speed possible, up to ≈ 10 m/s

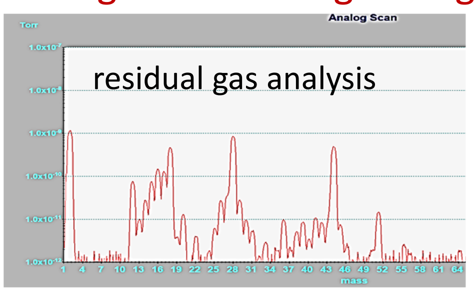




Magnetic field reduces below Earth's magnetic field by ≈ 30 mm distance

Standard PowerProbe

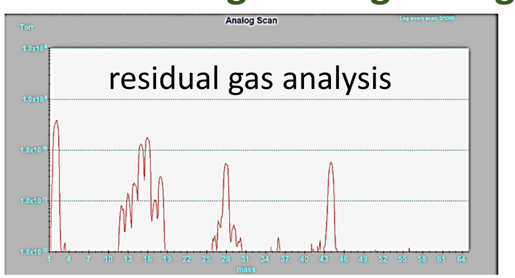
Sliding PEEK bearing arrangement



- May introduce trace levels of organic material
- Pressure increase ~2 decades during translation

XPowerProbe

Metal rolling bearing arrangement



- Ultra-clean operation
- <1 decade pressure increase during translation
- < 0.5 Linear friction of standard Power Probe

Novel Metal Sealing for large Flanges

Talk by Martin Lemke on behalf of DESY

Challenge: No CF-fange-type gaskets possible for large rectangular flanges

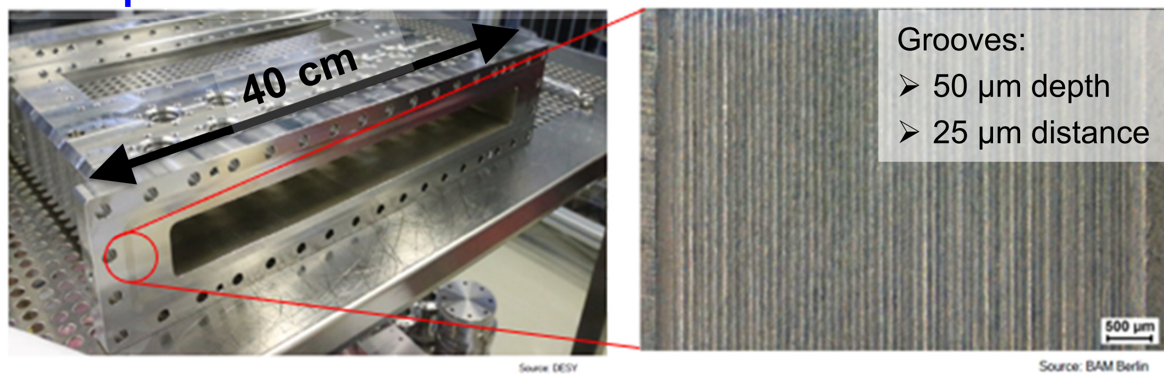
Novel sealing technique: Many small grooves to press gasket

Advantage: Lower precision needed as for flat surface sealing

Result:

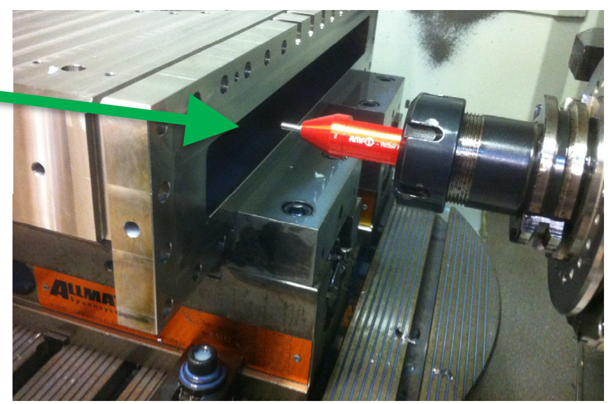
- Production method established
- UHV performance approved
- At least 20 time reusability
- Suitable for all flange shapes

Example: XFEL BPM camber



Commercial 'AMF-Writer'

Production on CNC using 'AMF Writer tool '



Conclusion

Mission accomplished:

- Workshop related to **one** special subject acts as addition to IBIC (not competitor)
- Large interest within the community (≈100 people online, discussion in breakout rooms)
- Thanks to all speakers and participants for very valuable contributions

Topics:

- Application of nanotubes
- Nano-fabrication of fine-structure elements
- New material and methods for in-vacuum applications
- Experiences and investigations concerning vacuum components
- Novel production methods of instrumentation

Documentation of each talk:

- Workshop web-site, https://indico.cern.ch/event/1031708/
- These IBIC proceedings

Thank you very much for your attention!

Back-up slides

Outgassing rates of Polymers for UHV Applications

Talk by Ivo Wevers on behalf of CERN

Challenge: Insulator for UHV applications

Method:

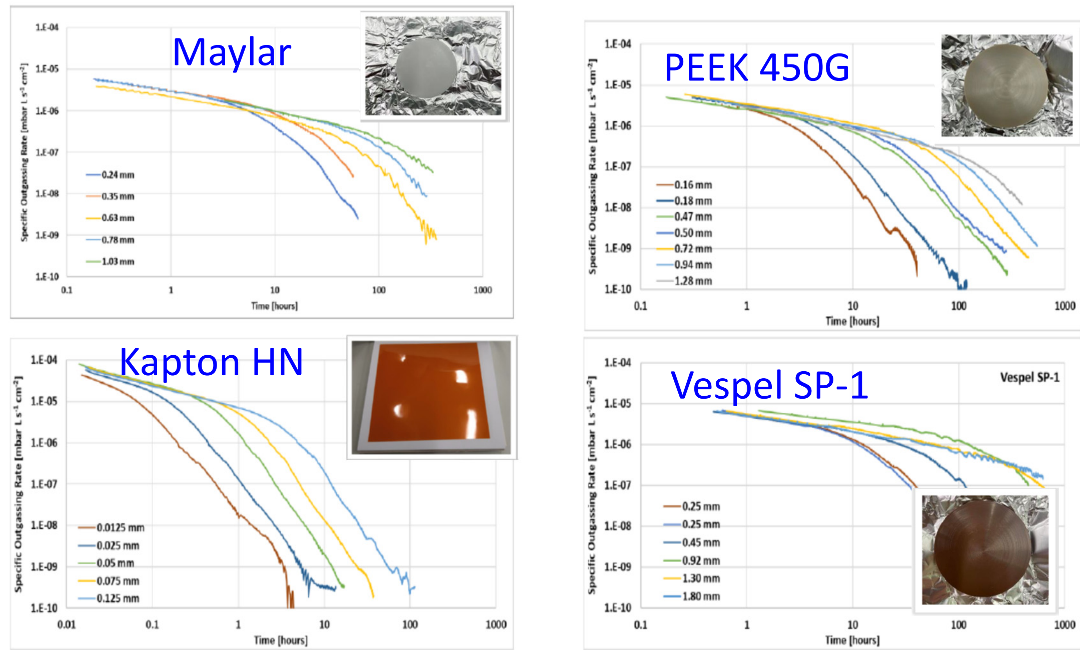
- Pumping speed measurement
- Residual gas analysis
- Comparison of
  Maylar, PEEK, Kapton & Vespel
- Relation to in-air storage

Result:

- Kapton has lowest outgassing
- Decrease outgassing by
  - Baking to 100 – 200^{0}C
  - Storage in dry atmosphere
  - Minimizing exposure to air

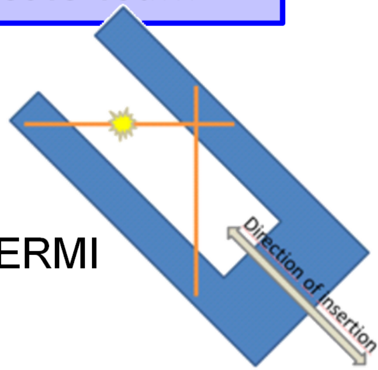
Quantitative 3-step model applied
(moisture evaporation and bulk diffusion)
Detailed report available

Example: Outgassing for different sample sizes as a function of time (log-log plot)



Ultra-thin Wire for linear Wire Scanner

Talk by Gian Luca Orlandi on behalf of PSI, Elettra and IOM-CNR Trieste team



Requirements: Spatial resolution of below 1µm ↔ thinner wire below ∅ 1 µm

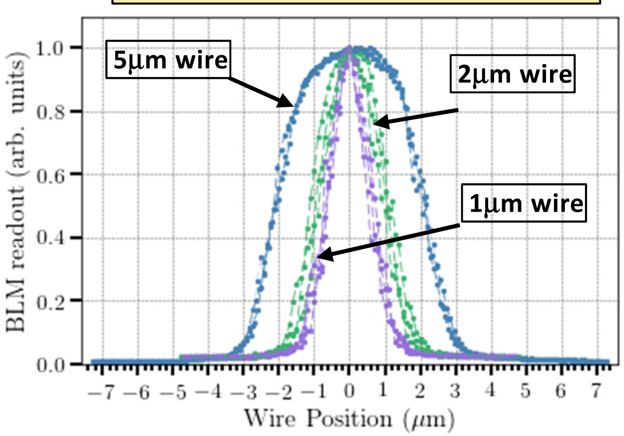
New techniques: Fabrication via Nano-lithography
with integration wire+fork in a unique structure

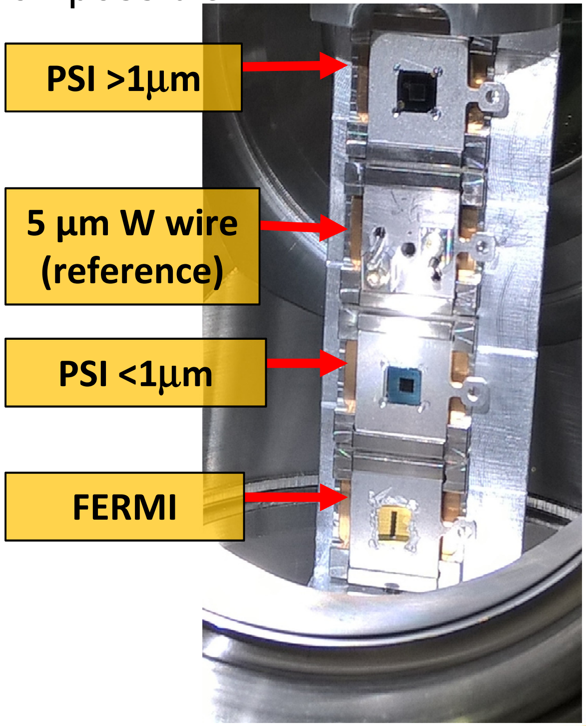
Present status: **Free-standing** WS independently nano-fabricated at PSI & FERMI

Result: Sub-µm spatial resolution ~250 nm, beam clearance ~ 2 mm
Tomography for quadrupole variation possible

Future plans: Beam clearance **~10 mm**

Test at SwissFEL PSI





'Ashby Diagram': Quantitative Selection Method for Wire Scanner

Talk by John Huber behalf of Engineering Dep. University Oxford and CERN

Requirements: High speed 20 m/s & acc. 15000 rad/s^2

$\Rightarrow$ mechanical stiffness

$\Rightarrow$ light (low-Z) material

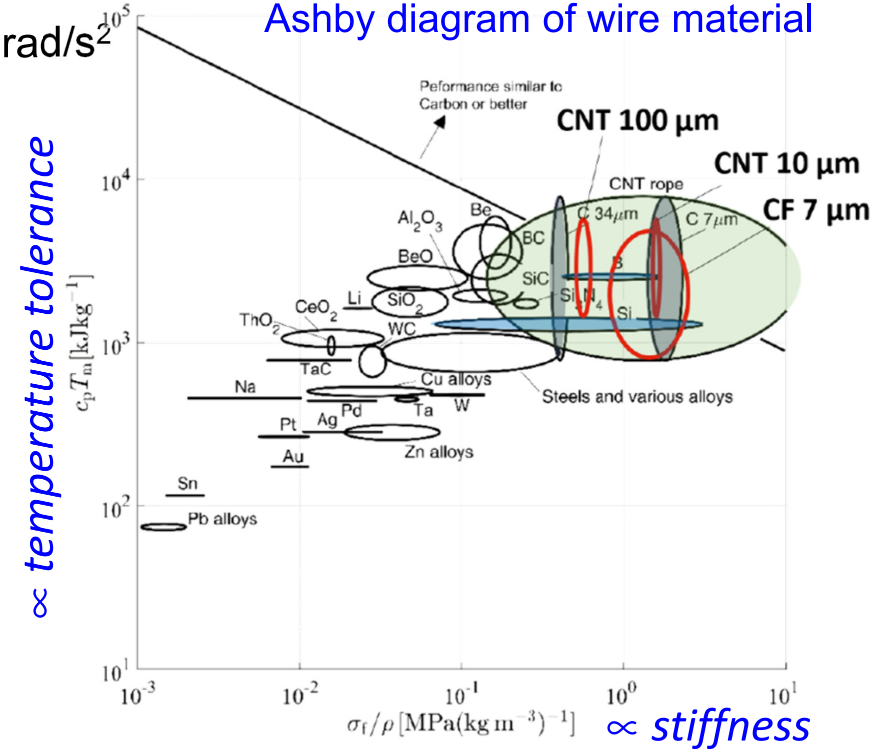
$\Rightarrow$ high temperature tolerance

Quantitative selection method: Ashby diagram

Result:

- Clear selection criteria
- CNT robes have superior performance
- Test of open topics performed
  e.g. stat. variation of breaking strength

Ashby diagram of wire material



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