Oak Ridge National Laboratory

LCWS2024 International Workshop on Future Linear Colliders

sX Mapping System Test at ORNL

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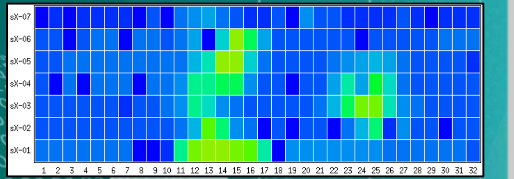
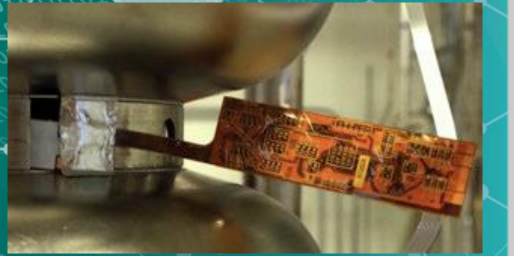


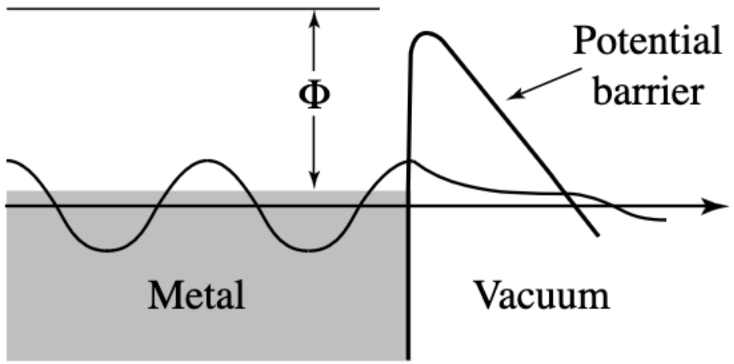


U.S. DEPARTMENT OF ENERGY

Outline

- Need for field emission suppression in high-gradient SRF systems
- Areas of interest
- sX mapping as instrument for field emission diagnostics
- sX mapping test on SNS high-beta cavity at ORNL
- Conclusion and outlook

Need for Field Emission Suppression



$$I_{\mathrm{FN}} = j_{\mathrm{FN}} A_{\mathrm{FN}} = A_{\mathrm{FN}} \frac{e^3 (\beta_{\mathrm{FN}} E)^2}{8\pi h \Phi t^2(y)} \exp\left(- \frac{8\pi \sqrt{2 m_{\mathrm{e}} \Phi^3}\, v(y)}{3 h e \beta_{\mathrm{FN}} E} \right)$$

$$y = \sqrt{\frac{e^3 \beta_{\mathrm{FN}} E}{4\pi \epsilon_0 \Phi^2}}.$$

J. Knobloch, Dissertation, Cornell (1997)

Snowmass 2021 LOI

Field Emission Suppression in High-Gradient SRF Cavity Systems

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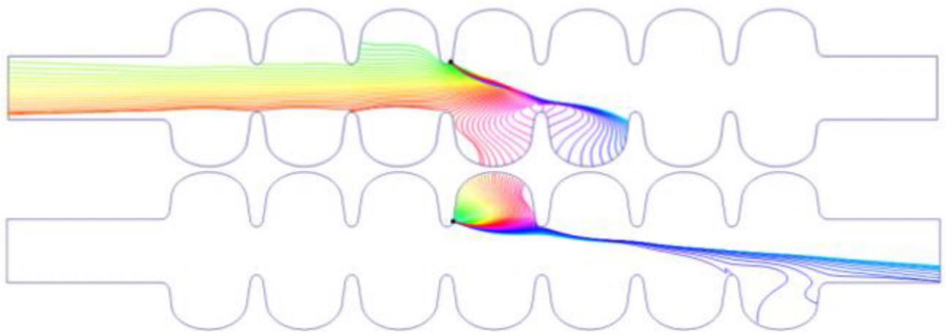
https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF7_AF7_Rongli_Geng-192.pdf

- Broad adoption of SRF cavities
- Continued rise in acceleration gradient
- Field emission a long-standing challenge
- Goal is reliable control and cure

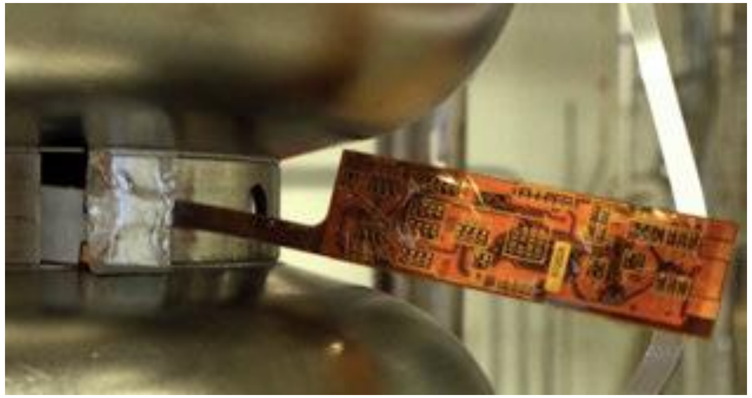
Areas of Interest

- Electron emission fundamental physics
  - Fowler-Nordheim theory
  - Emitter physics (surface oxide, adsorbates frozen gases, particulates, mechanical irregularities)
- Emitter detection
  - T-mapping (vertical testing R&D cavities)
  - **X-ray mapping**
  - Reconstruction via remote X-ray detection plus electron ray tracing and computational radiation production
- Curing field emission
  - Reduce emitter sources
  - Block emitter transport to SRF surfaces
  - Inhibit emitter activation/in-situ emitter destroy
  - In-situ emitter removal and reversal transport

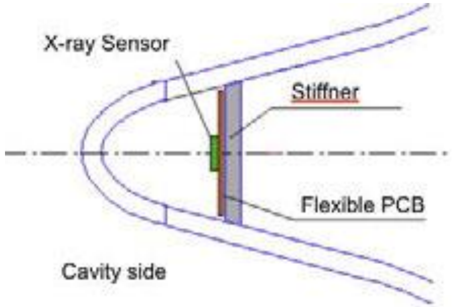


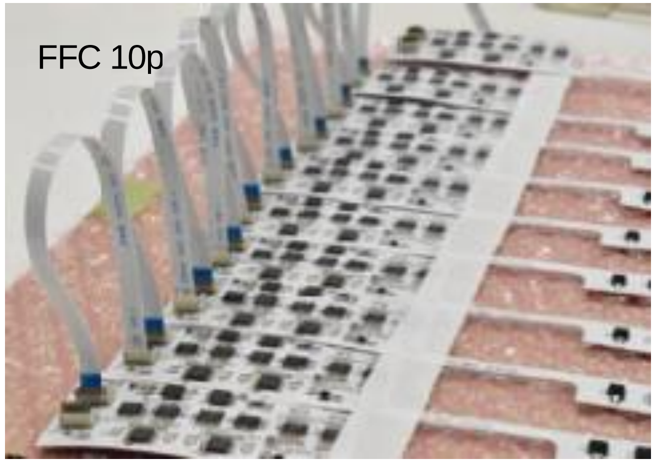
sX-mapping as instrument for field emission diagnostics

Each strip has 32 photodiodes and the 32 charge signals are integrated and multiplexed in the strip.
For a 9-cell cavity, typically 10 strips will be used and daisy-chained together. In this case, 320 analog signals are sequentially scanned and transferred to the room temperature side for A/D conversion ≦10 Hz.



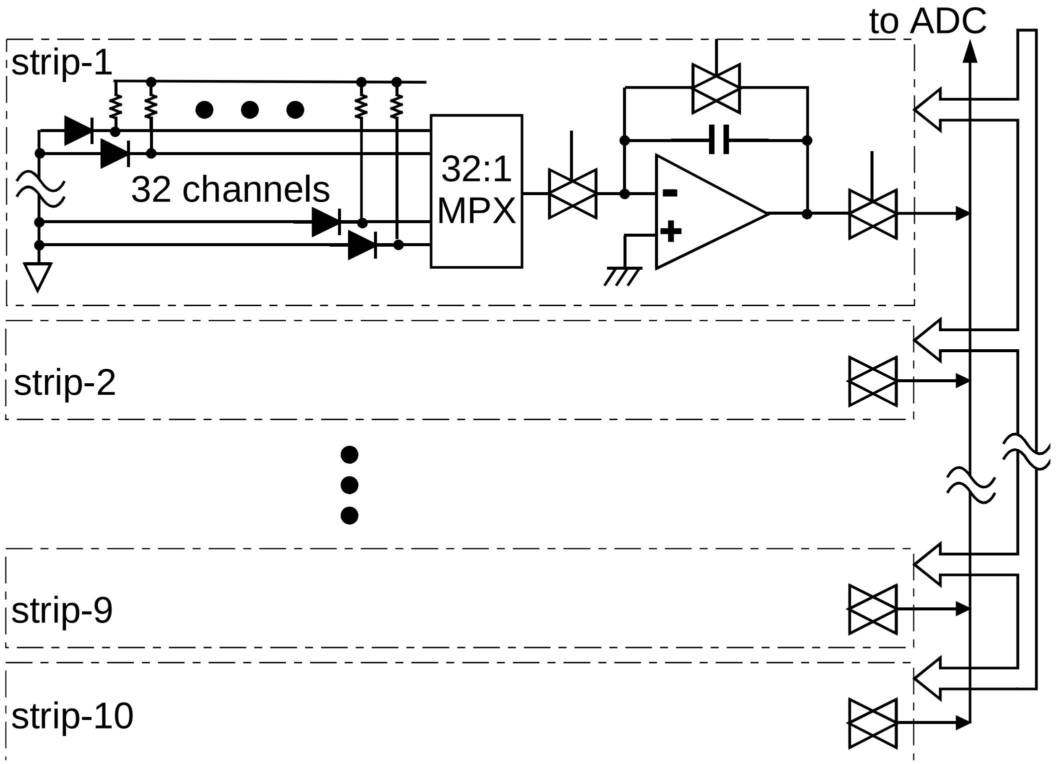
Inserted sX-map strip Ver.3





Daisy chained sX-map strips Ver.4

LSF-5 with sX-map strips Ver.3

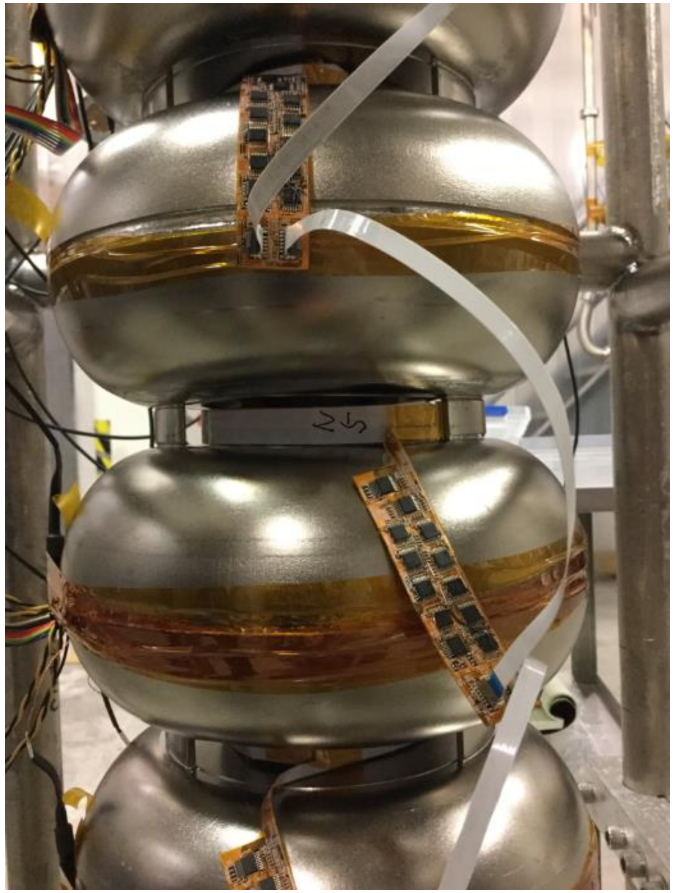


Block diagram of the system:
Only 10 lines are needed including power and control lines.
CMOS ICs work fine even at Cryogenic temperature.

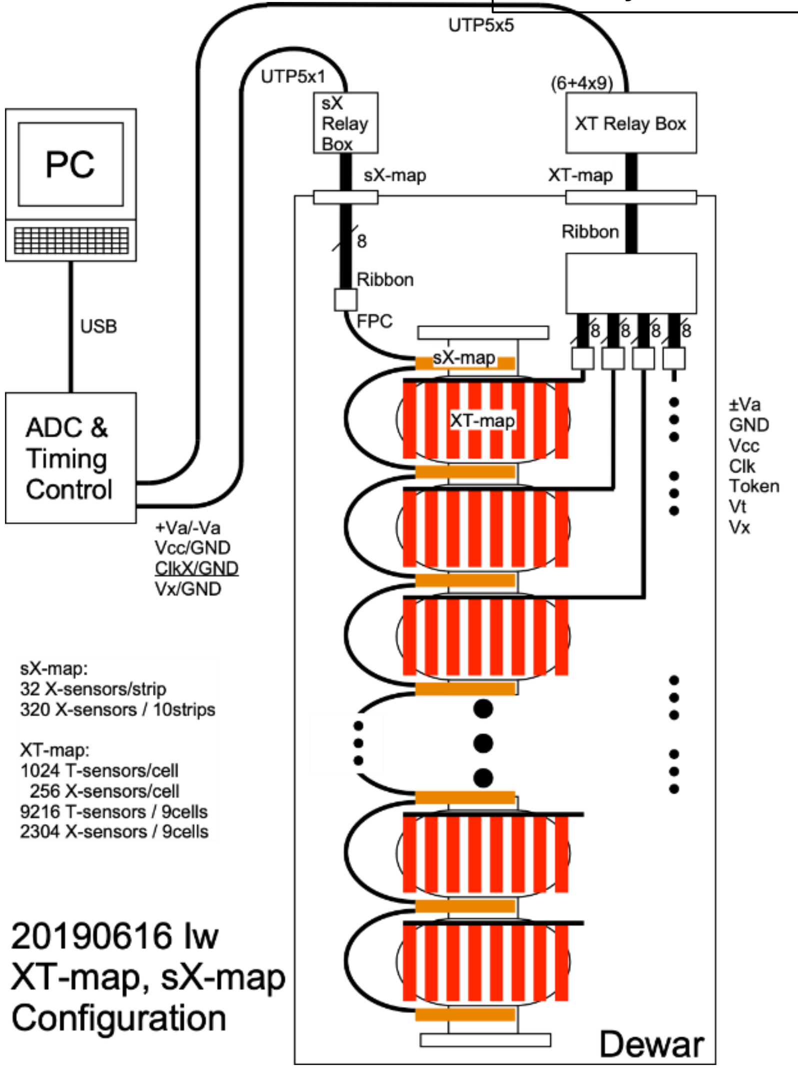
"s" in sX map stands for strip/stiffener ring

sX-mapping Testing on 1.3 GHz 9-Cell LSF Cavity at JLAB

New sX-map on LSF-9
(Reduced power consumption
& Gain control)

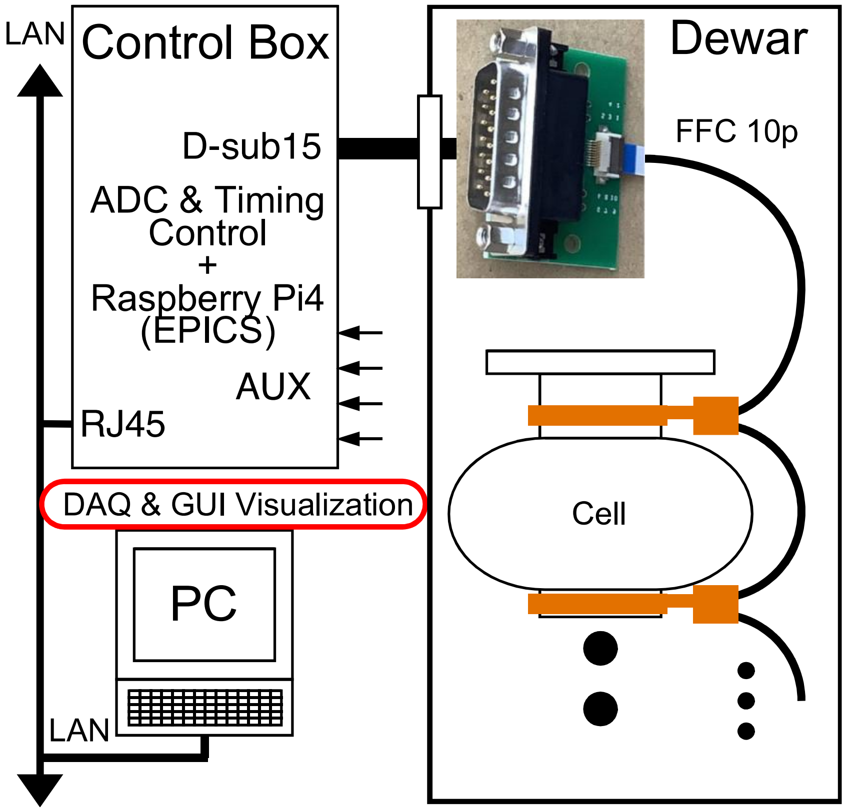


KEK-Kyoto-JLAB



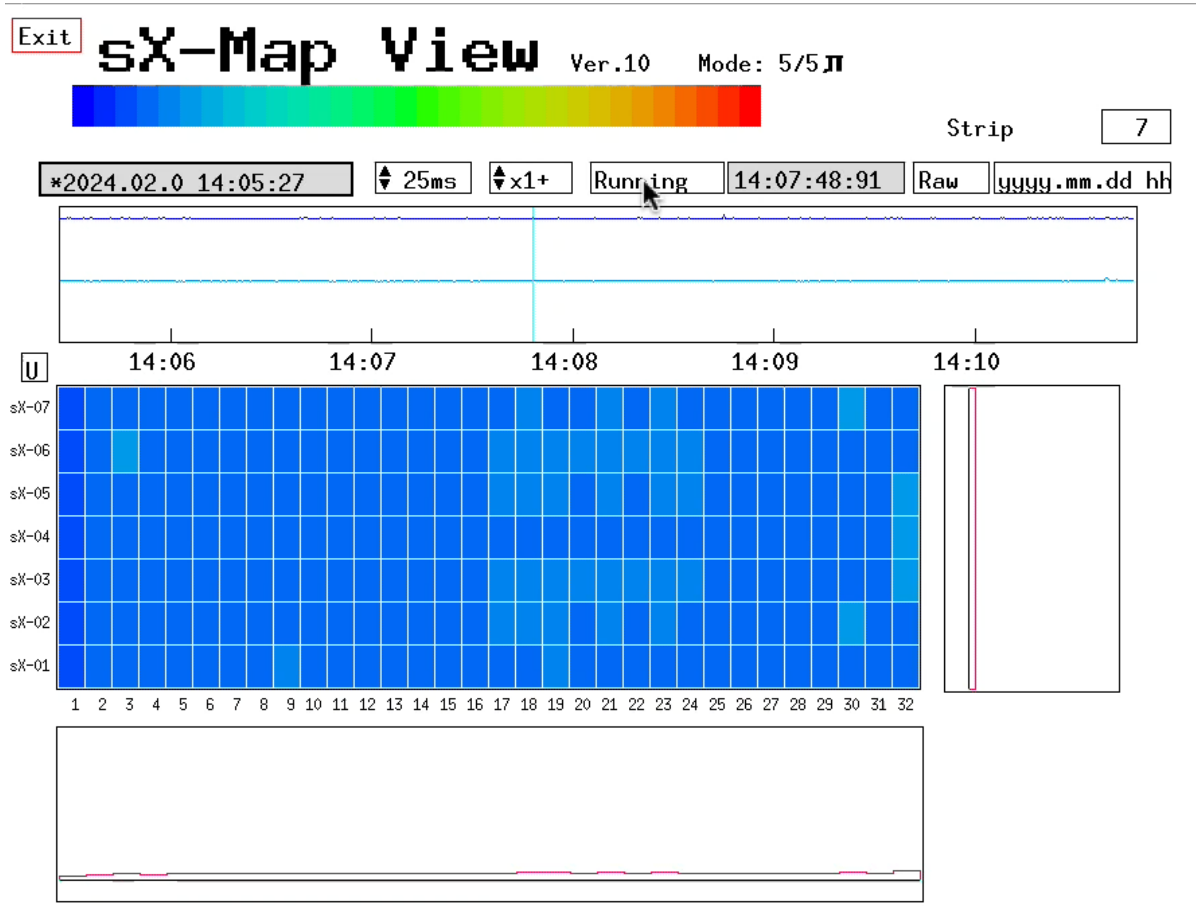
sX-mapping Testing on SNS High-Beta Cavity at ORNL

320 analog signals are transferred to the room temperature side to be A/D converted up to 10 Hz.
The collected data is assembled and handled through EPICS by Raspberry Pi.
The resulted map can be visualized as a movie by GUI.



sX-map Configuration

SNS cavity with sX-map V.4



Movie Example

Experimental Setup in VTA at ORNL and Results

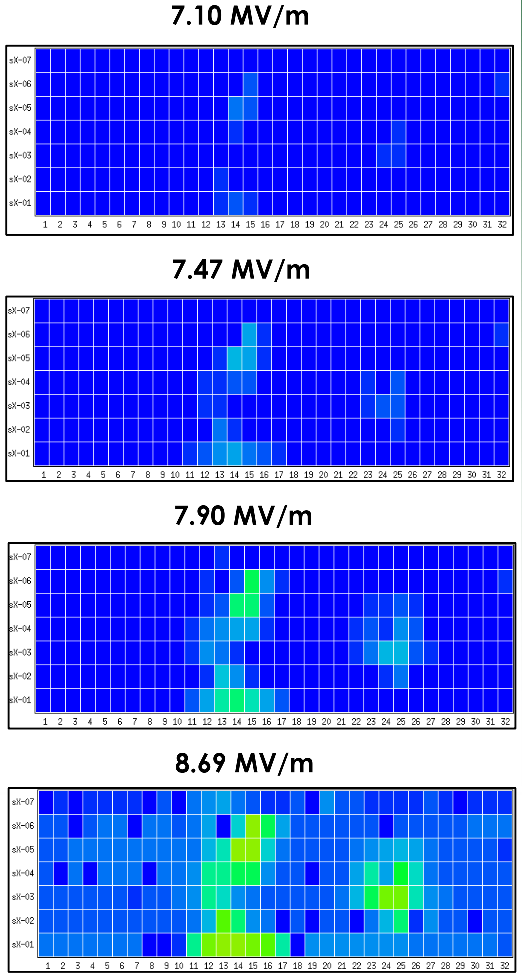
New system installed on SRF cavity

- sXmap strips installed at the 5 irises and 2 ends of the SRF cavity (7 total)
- Sensors surrounds the cavity irises – identify where the x-ray produced by field emission hit the cavity
- Very close to the cavity and triggered by low intensity x-ray – very sensitive measurement

Figure 2: sXmap system mounted on HB60 SRF cavity

Early results

- System installed on SNS 6-cell spare cavity (HB-60) known for field emission onset at ~8 MV/m
- The blue squares shown on the laptop are the sXmap sensors
- As the cavity gradient increases, the sensors detect x-rays (field emission) being produced inside the cavity



Conclusion and Outlook

System successfully tested on SNS cavity:

- Field emission detected around the gradient value we expected (8 MV/m)
- The sXmap sensors detected field emission at much lower gradient (~7.5 MV/m) than the photomultipliers installed above the dewar – <u>much more sensitive</u>

Next steps:

- Use the sXmap system to qualify our cavity cleaning procedures (HPR and cleanroom procedures)
- Potentially order new sensors to cover the equator of the cavity as well as the irises
- Improve the sXmap software user interface