Nb_3Sn COATING OF COMPLEX SRF CAVITY STRUCTURES*

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ABSTRACT

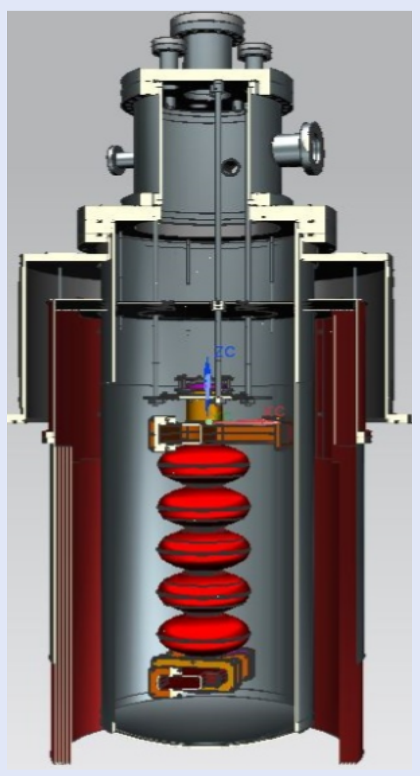
Superconducting thin films have the potential of reducing the cost of particle accelerators. Among the potential materials, Nb_3Sn has a higher critical temperature and higher critical field compared to niobium. Sn vapor diffusion method is the preferred technique to coat niobium cavities. While majority of the research efforts are currently focused on the development of elliptical single-cell and multi-cell cavities, the potential of this material is evident to other cavity types, which may have complex geometries. We are working towards the development of Nb3Sn- coated Half-wave resonator and Twin-axis cavity at JLab. The Half-wave resonator with a coaxial structure provides data across different frequencies of interest useful for particle accelerators worldwide, whereas the twin axis cavity with two accelerating axes has been proposed for the Energy Recovery Linac (ERL) applications. With their advanced geometries, larger surface area, increased number of ports and hard to reach areas, the usual coating approach must be evaluated and may need to be adjusted. We are commissioning a secondary Sn source in the coating system and will modify the current coating protocol to coat different complex cavity models.

Nb_3Sn AND CAVITY DEPOSITION SYSTEM AT JLAB

Nb_3Sn

- Higher Critical temperature of 18.3 K
- Low surface resistance ⟶ Lower cost accelerators

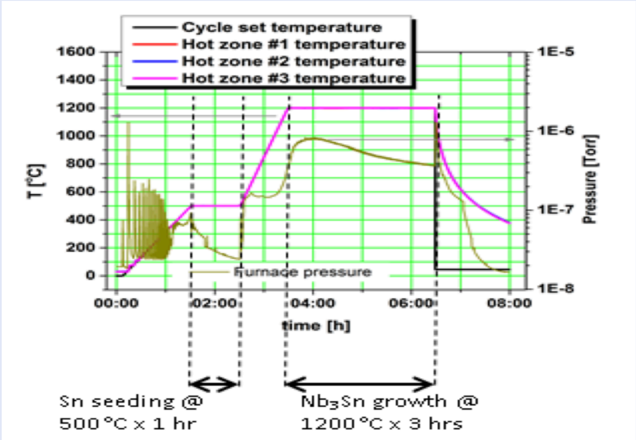
- Brittle material
- Thermal conductivity is 1000 times lower than Nb at low temperatures ⟶ Thin film layer



Nb_3Sn coating system.

Cavity deposition system at JLab

Nb_3Sn deposition system at JLab contains two main parts:
- coating chamber that hosts the cavity to be coated - built out of niobium as a 40" long x 16" diameter cylinder.
- furnace that provides the desired heating to the coating chamber [1] - commissioned to reach 1250 ^{0}C with the furnace vacuum in 10^{-7} Torr range.

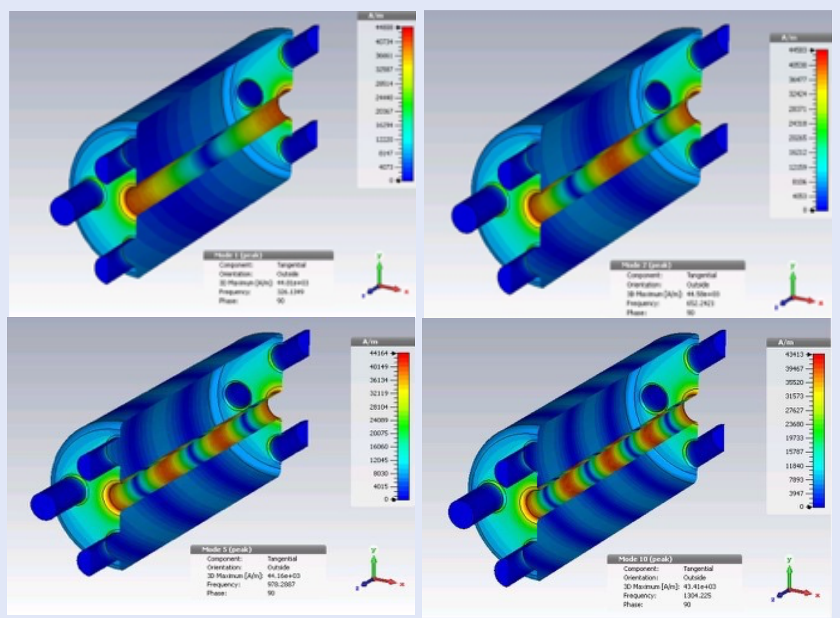


The temperature profile used for coating Nb cavities[2].

The typical coating process at JLab consists of,
- a nucleation step which involves the tin chloride evaporation at 500 ^{0}C for 1-hour.
- a deposition step which involves the evaporation of tin for 3-hours at 1200 ^{0}C, which is favorable to form Nb_3Sn phase on substrate niobium [2].

HALF-WAVE CAVITY

- Cylindrical-coaxial resonator which has TEM modes other than TE and TM modes , allowing data across wide range of frequency.
- The high surface magnetic field is concentrated on the inner cylinder.
- Center for Accelerator Science (CAS) at ODU recently developed another half-wave cavity (frequency range of 325MHz to 1.3GHz) and ready for the baseline RF tests.



Surface magnetic field distribution of the TEM1, TEM2, TEM3, and TEM4 modes (CST Studio).

Cavity Parameters

Parameter	Unit	Value
Cavity length	mm	459
Outer conductor radius	mm	111
Inner conductor radius	mm	20
Peak electric field, E_p	MV/m	15.6
Peak magnetic field, B_p	mT	56
TEM1, TEM2, TEM3, TEM4 frequencies	MHz	327.7,655.3, 982.9,1310.5
Geometric factor, G	Ohm	61,123,185,247

Complete half-wave coaxial resonator.

Inner conductor sub assembly.

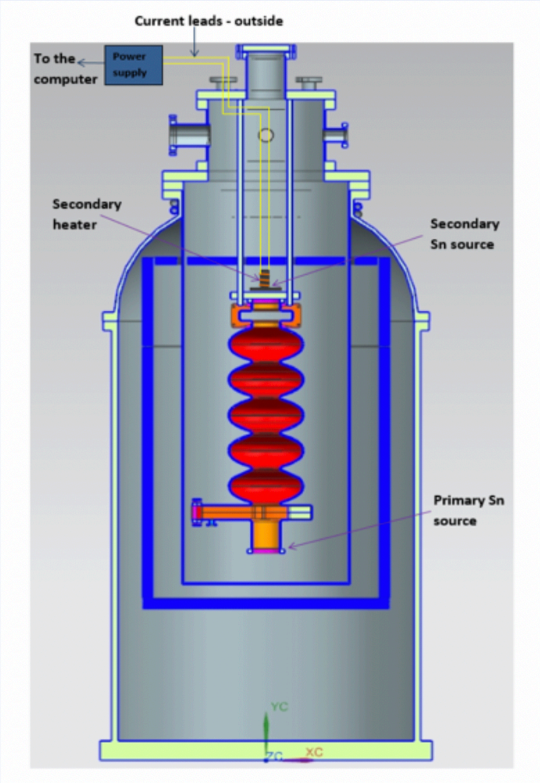
SECONDARY TIN SOURCE – DESIGN AND FABRICATION

- Low tin flux from a single tin source.
- Increased area , increased number of ports
- Temperature gradient through the cavity .

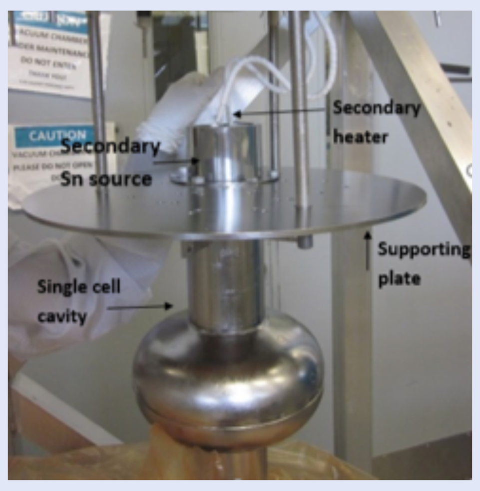
⟶ New crucible to host a secondary tin source and a heater from top.

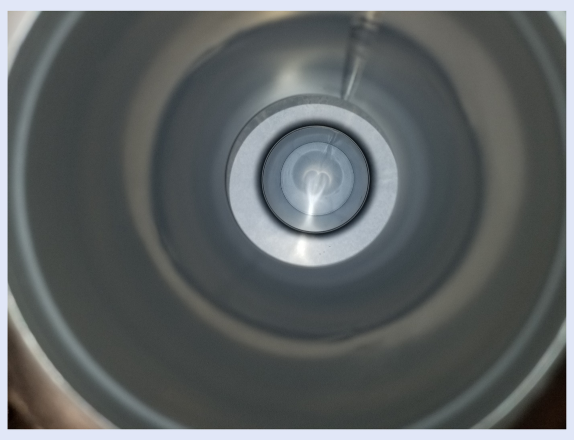
Secondary Sn Source


Secondary Sn source (Left) and the heater (Right).



Cavity coating system model with the secondary Sn source and the heater with a 5- cell cavity.

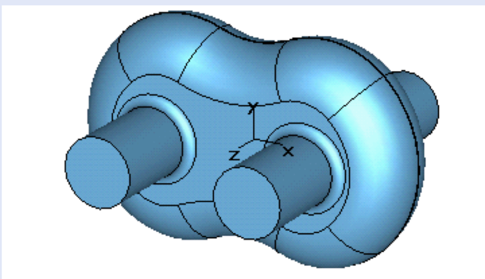




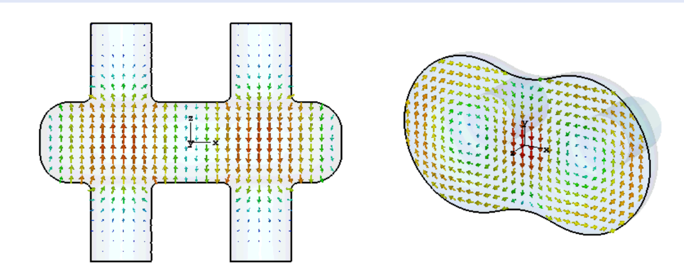
Single cell assembly with the secondary Sn source and the heater (Left) and inside the coated cavity (Right).

TWIN AXIS CAVITY COATING

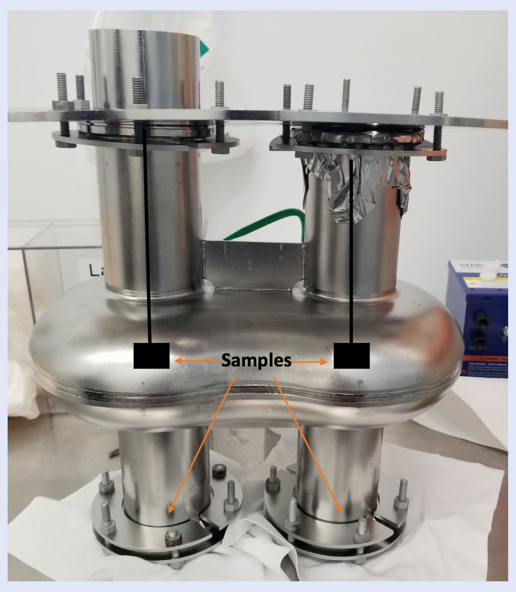
- Two beam axis structure - improve ERL performance
- Two cavities are fabricated with 1497MHz TM_{110} dipole mode frequency [3].
- Coated with the same temperature profile using two Sn sources and ready for the RF test.



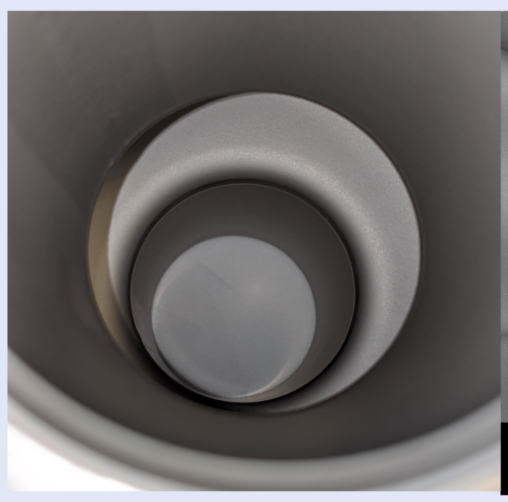
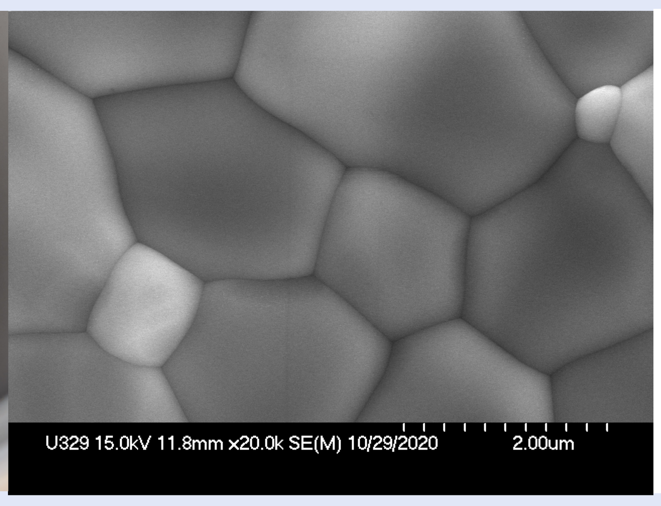
Twin axis cavity.

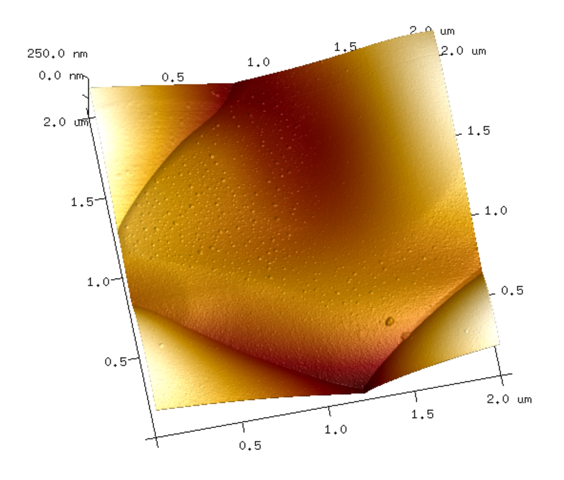


Electric (left) and magnetic (right) field profile at the twin cavity cross section.



Cavity assembly for coating.



Inside the coated cavity (left) ,SEM (centre) and AFM (right) images of the samples.

SUMMARY AND FUTURE PLANS

We have designed and fabricated a new crucible to host the secondary tin source, which we believe will help to produce a uniform Nb_3Sn coating inside a cavity with complicated geometry The secondary Sn source and the heater have been commissioned with a single-cell cavity. The half-wave cavity is at the finishing stage prior to the base line test. We plan to coat a half-wave cavity within the next few months and then move into the other complex cavities. Twin axis cavity is coated and ready for the testing.

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[2] U. Pudasaini, G. Eremeev, Charles E. Reece, J. Tuggle and M. J. Kelley, "Insights into formation of Nb_3Sn film during the vapor diffusion process", in *Proc. SRF'17*,China, pp. 539-542
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