Effects of Transverse Loads and Pure Bending on the Critical Current of Nb_3Sn Superconductors

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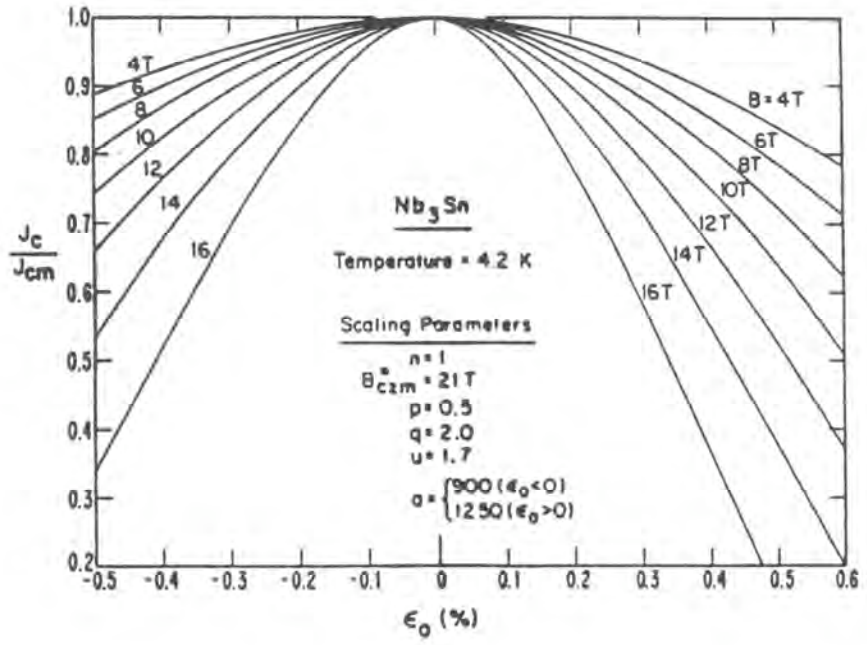
VLT Technical Highlight
September 14, 2005

Background

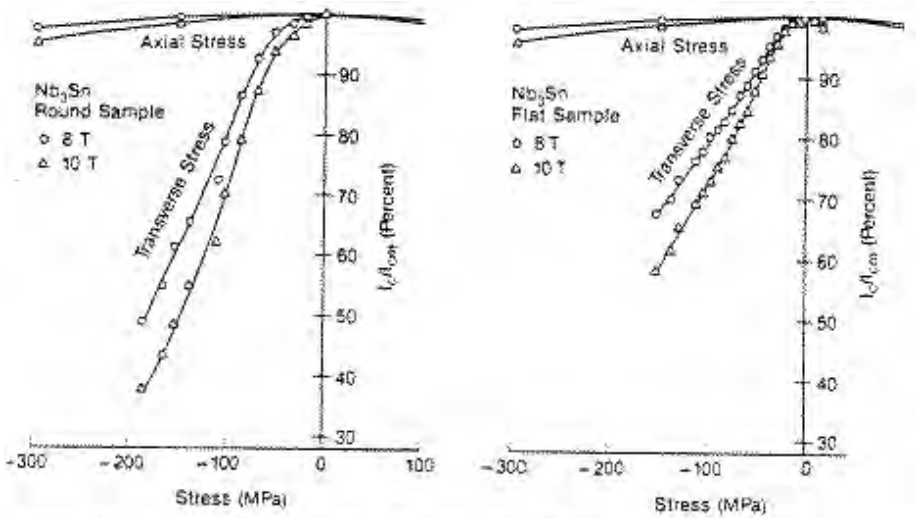
- Nb_3Sn is a brittle A15 intermetallic compound whose superconducting properties are known to be extremely sensitive to strain:
  - Historically most strain dependent characterization has been measurement of critical current or critical field as a function of applied uniaxial longitudinal strain
  - Co-processing with other materials (copper stablizer, structural jacket materials) with different Coefficient of Thermal Expansion (CTE) may lead to substantial thermal strain-induced degradation of critical current density

Data by Jack Ekin-NIST



Background (cont'd)

- Transverse compressive strain also is known to degrade critical properties.
- Bending strain results in both compressive and tensile strains in the superconductor cross-section



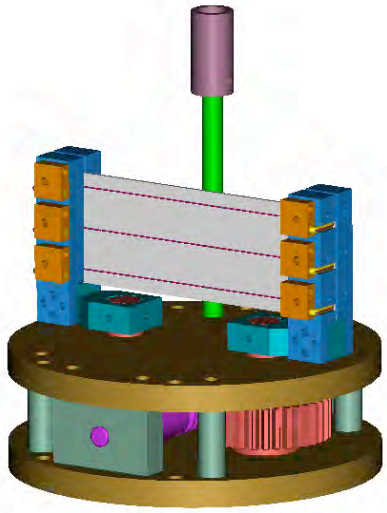
J.W. Ekin, "Transverse stress effect on multifilamentary Nb_3Sn superconductor"

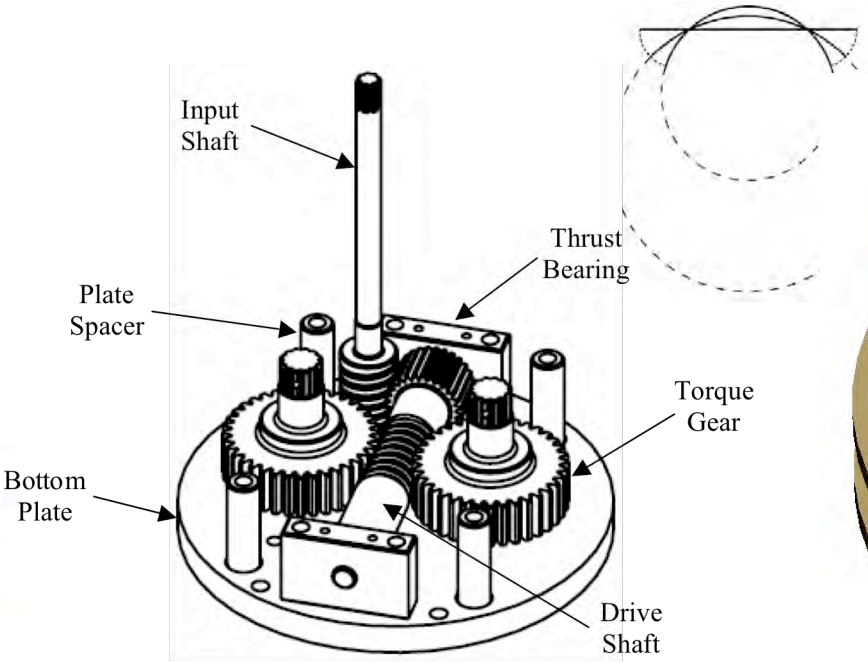
The effect of transverse stress is much larger than that of longitudinal stress for multifilamentary strands

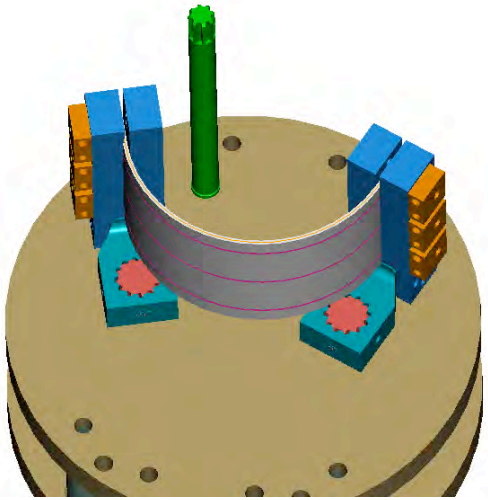
This work is focused on understanding the effects of transverse compression and pure bending through analysis and 3 lab experiments:

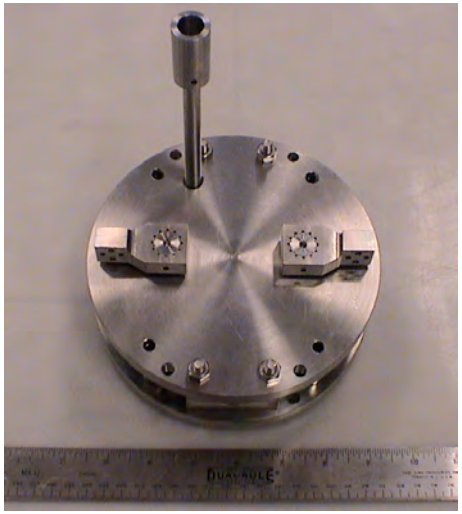
1. Pure bending in a single strand
2. Fixed bending in a single strand and measurement of filament breakage
3. Transverse compression in a multistrand cable

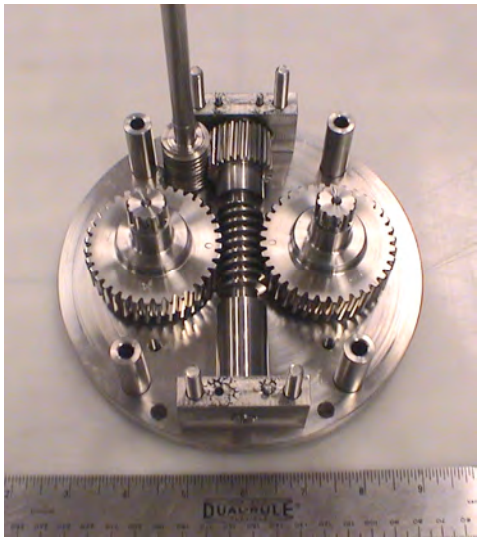
Pure Bending Apparatus

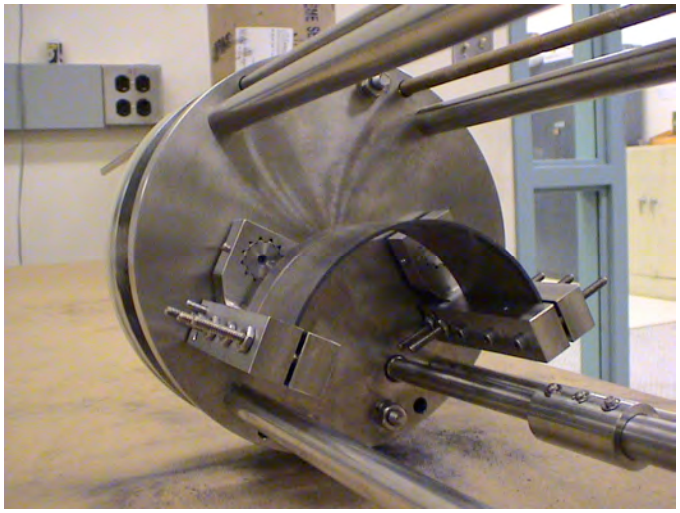






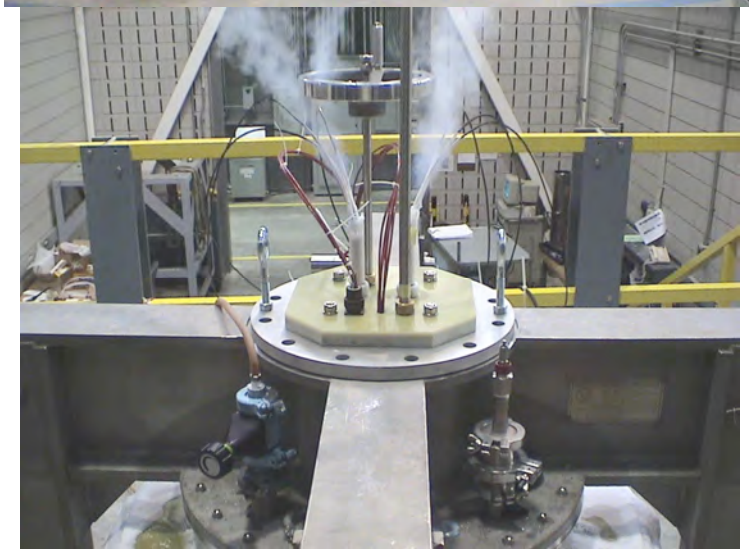


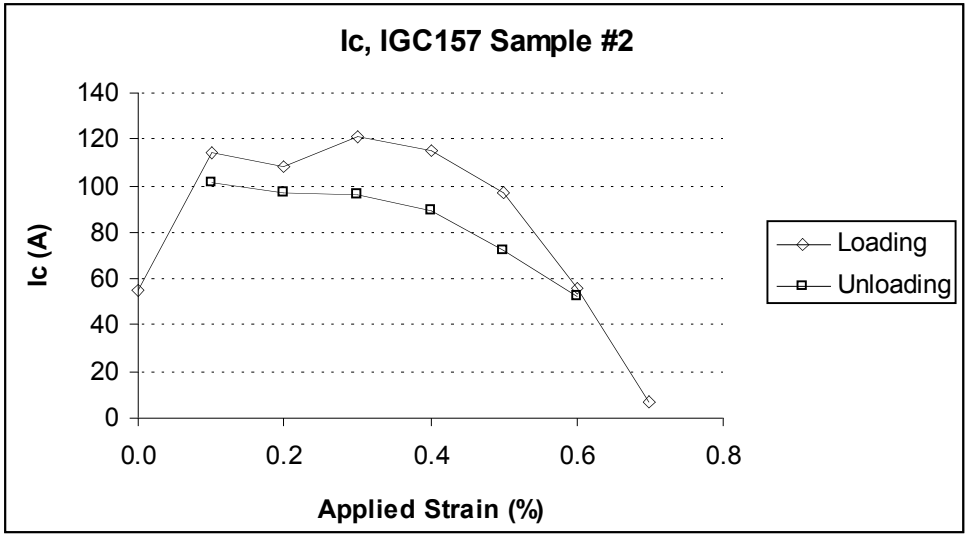


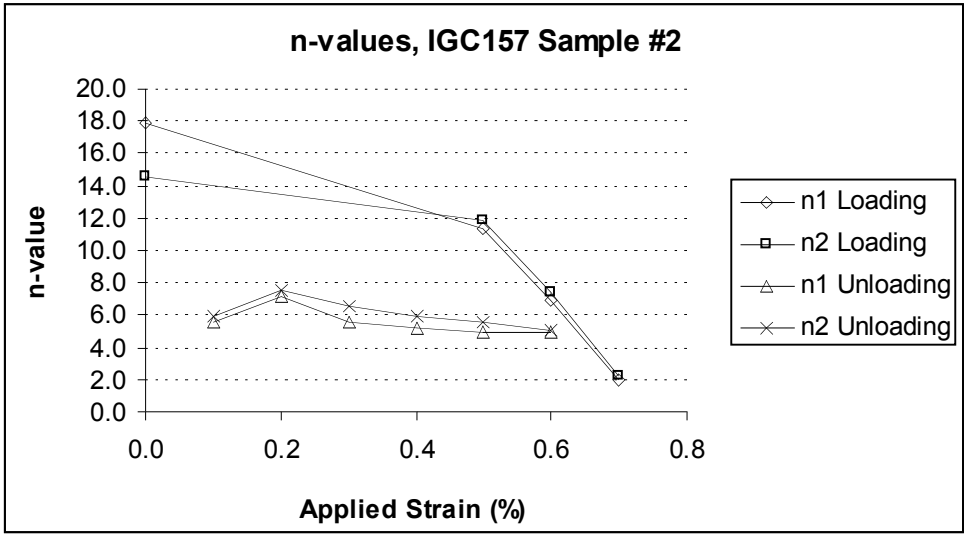


Pure Bending Apparatus (cont'd)

- Measurements performed in high field magnet at NHMFL, FL



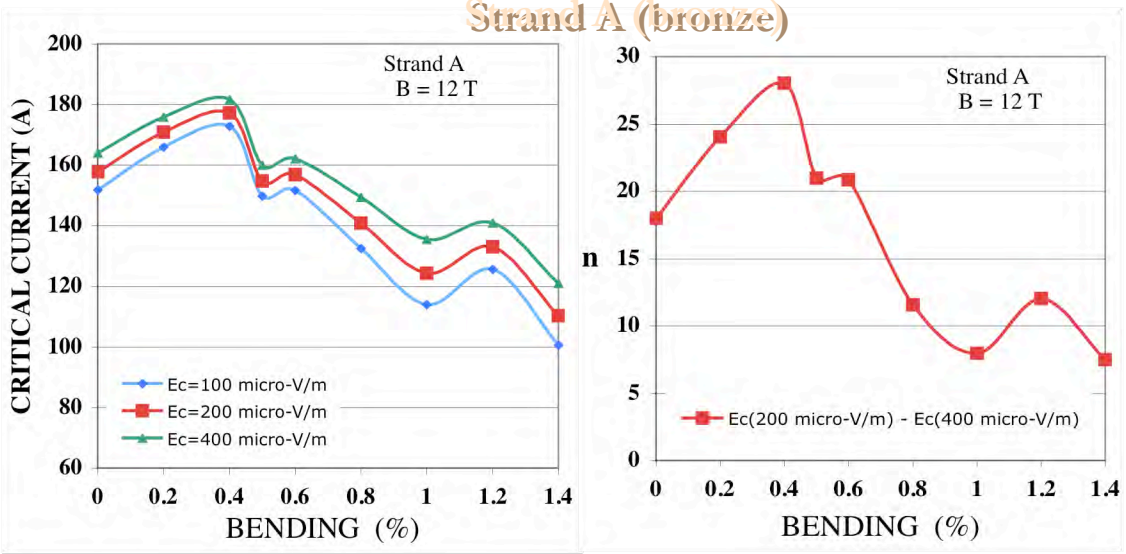




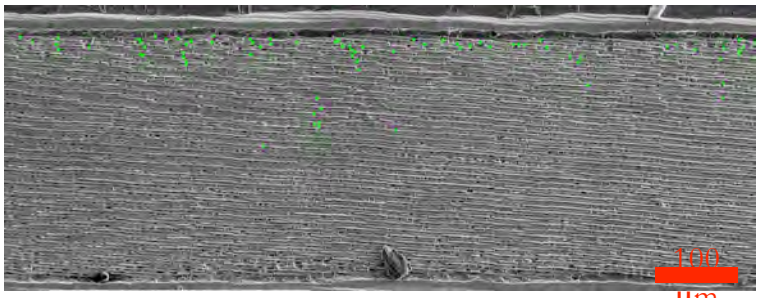
Fixed Bending Experiment

- Measurements performed in high field magnet at NHMFL, FL
- Crack analysis at UW- Applied Superconductivity Center

Strand A (bronze)

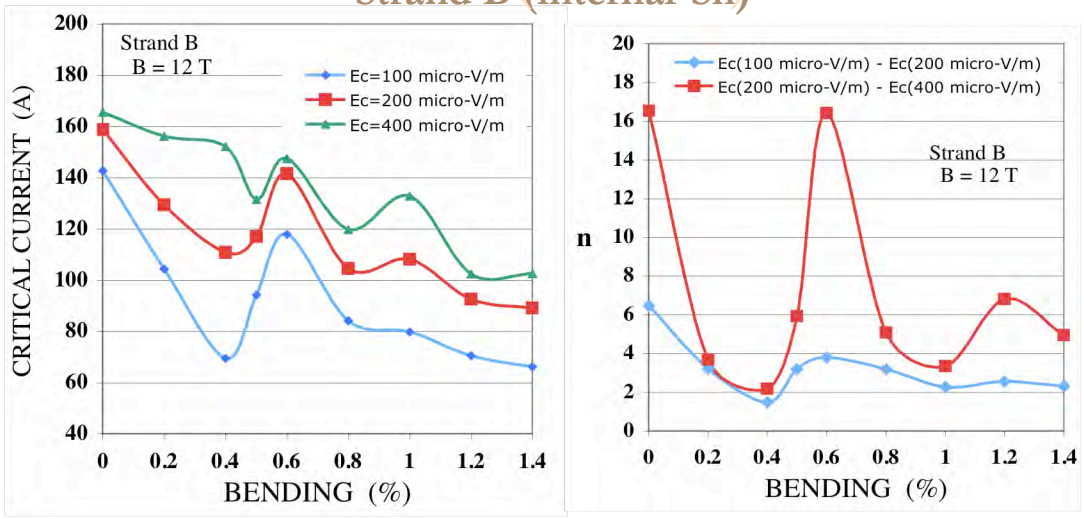


1.4%

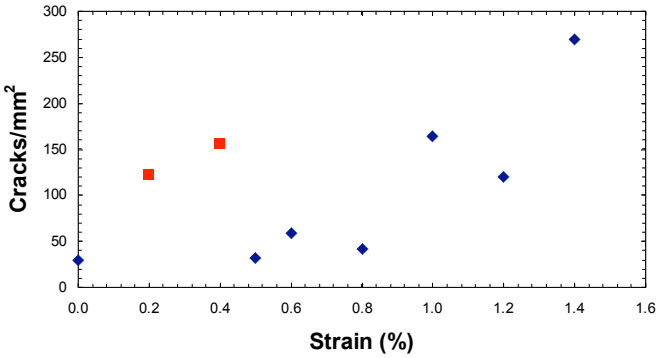


Cracking is clearly bend-related and more dense than at 1.0%

Strand B (internal-Sn)



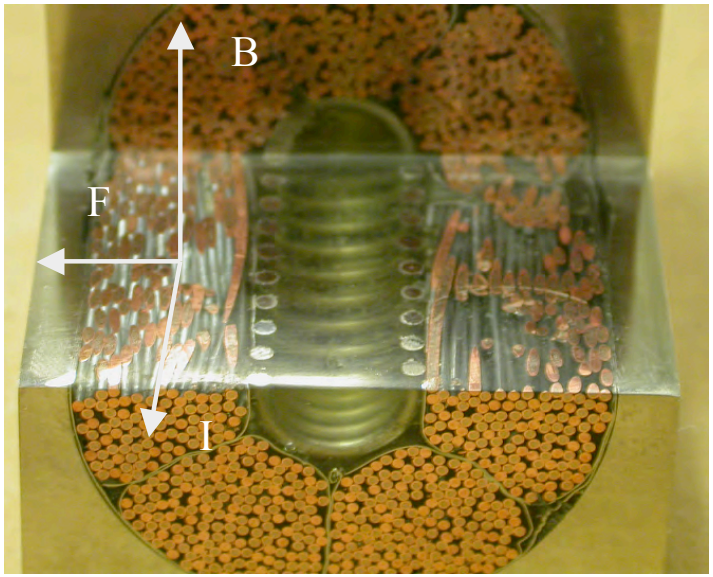
Crack density analysis

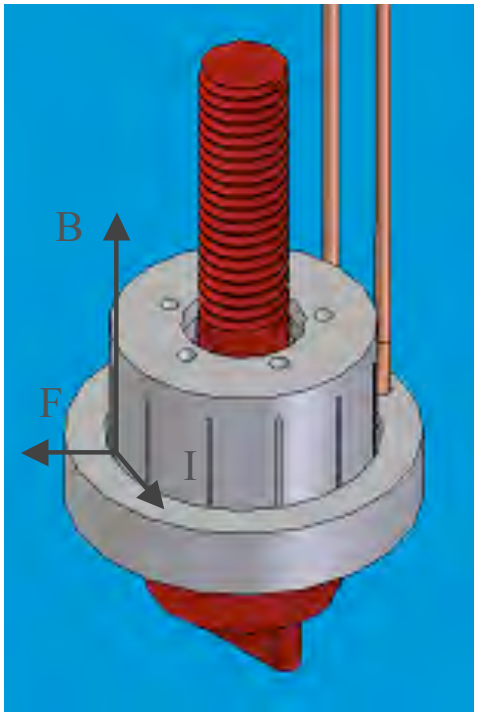


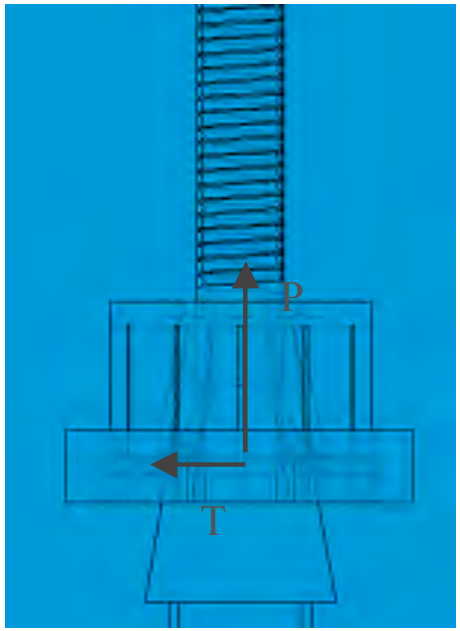
Peter Lee is in contact with Eliot Specht at ORNL to attempt micro-crack imaging by X-ray scattering

Transverse Compression in a Cable

- Apply transverse force on a cable to simulate Lorentz force effect which exists in real CICC
- Maximum external field applicable at NHFML is 20 T, maximum current is limited to 10 kA but it is NECESSARY to apply extra force to simulate operation conditions

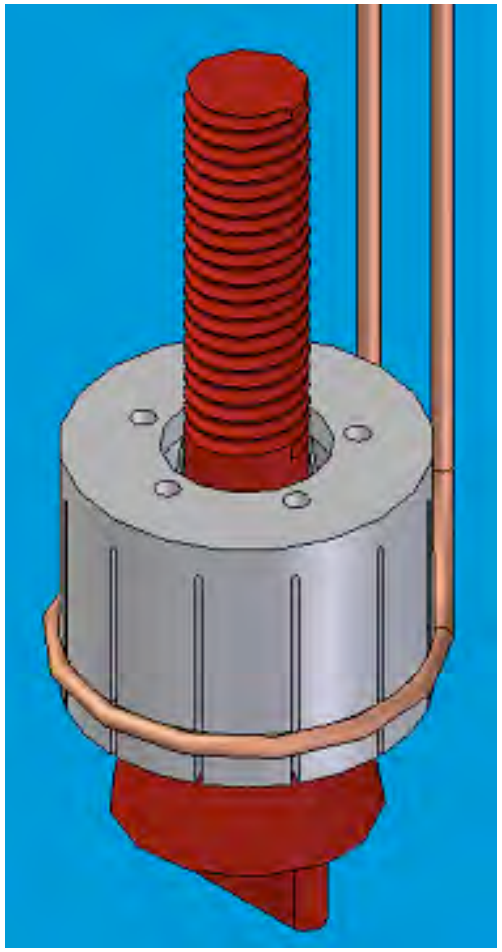






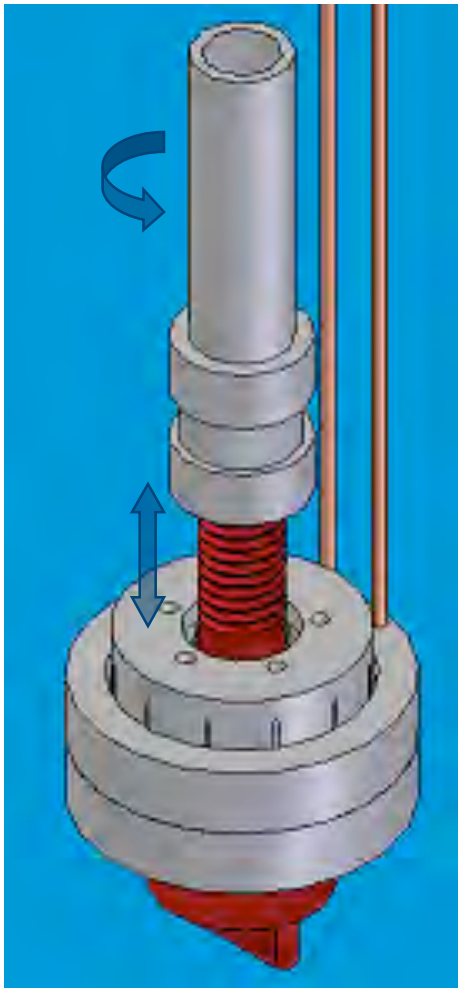
$$T = \frac{P \cdot (\cos\alpha - \mu \sin\alpha)}{2\pi \cdot (\sin\alpha + \mu \cos\alpha) \cdot \tan\alpha}$$

Description of device

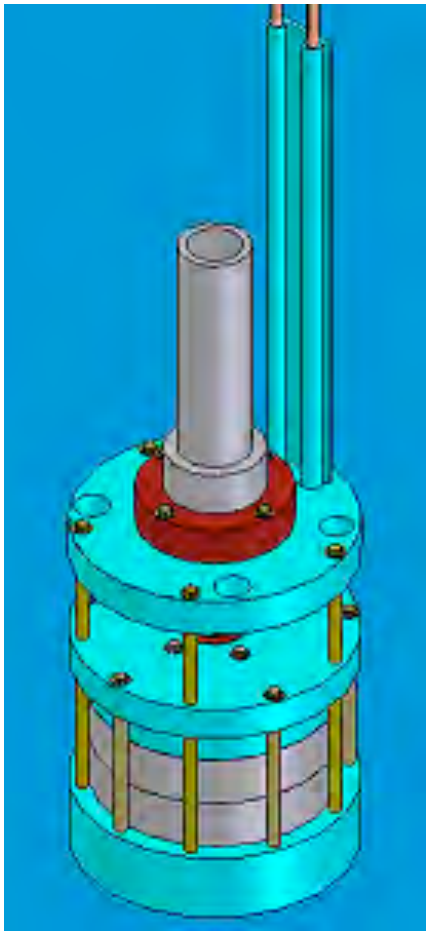


36 strands cable, IGC SC strands

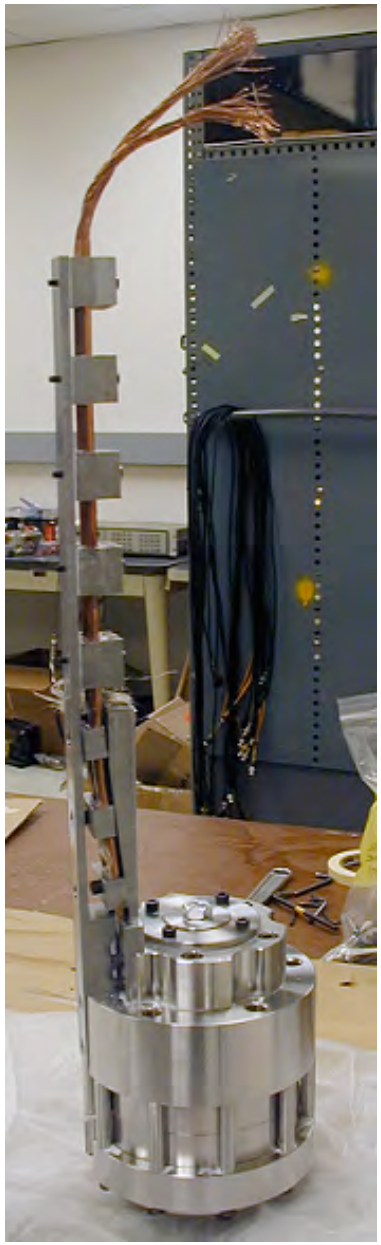
Internal ring is a collet and expands outward



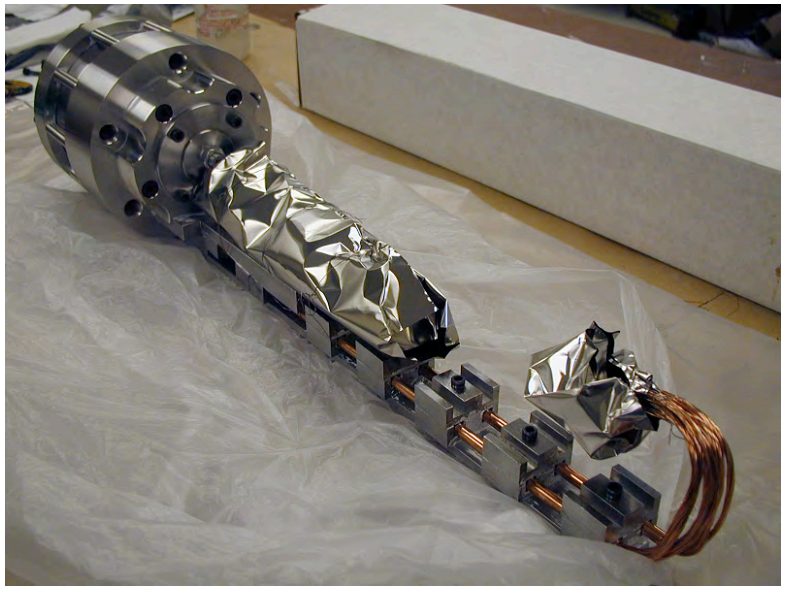
SC cable enclosed in between two rings

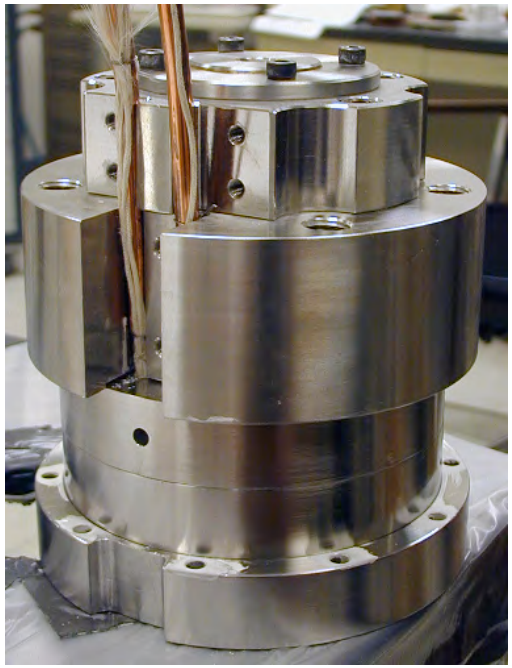


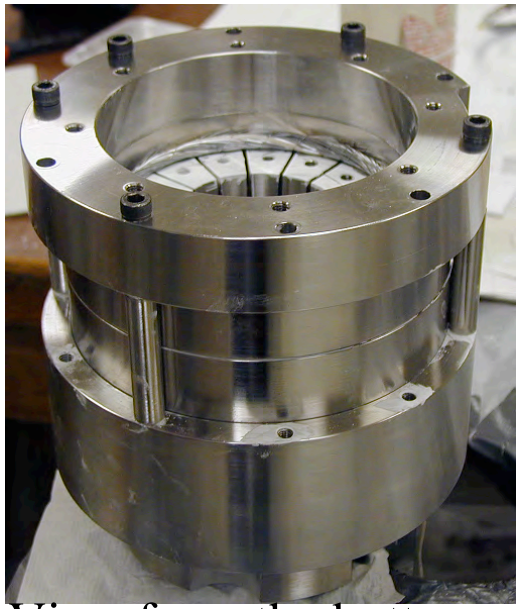
OD dewar 170mm



Structure ready for heat treatment

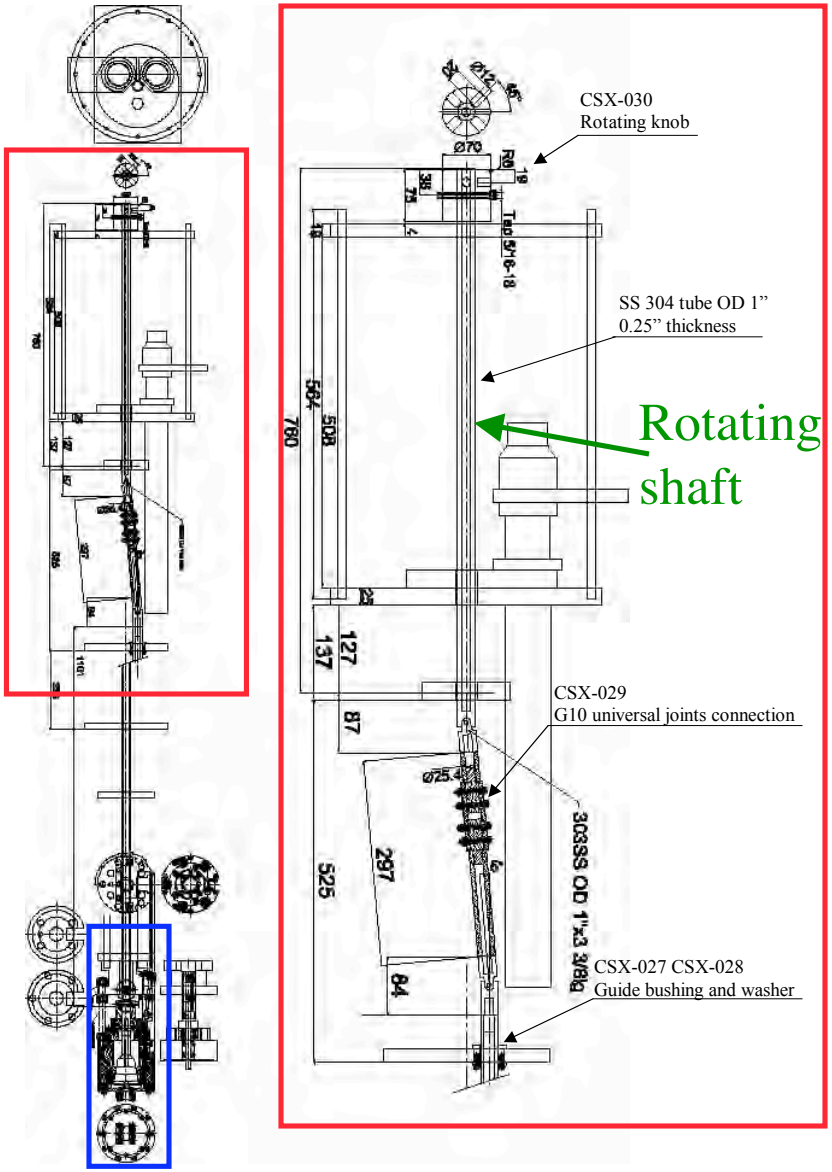


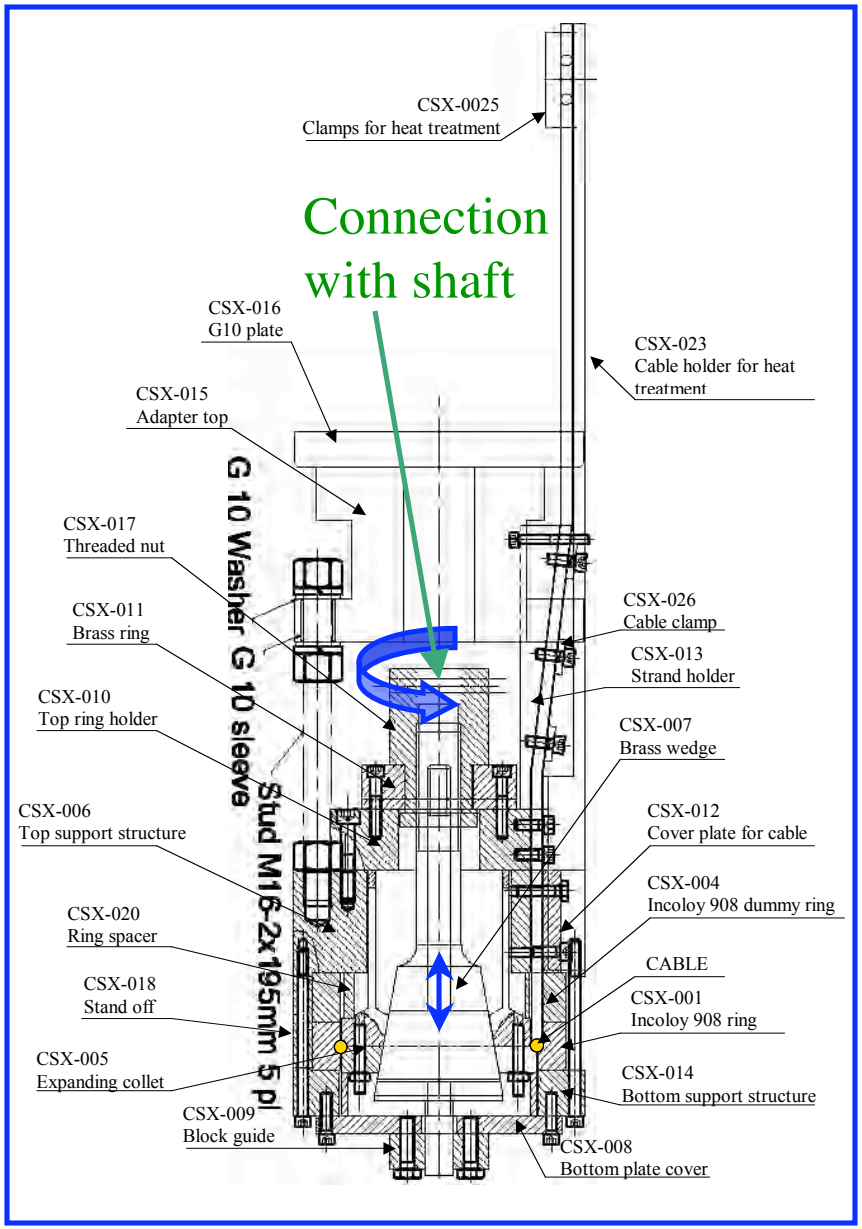




View from the bottom

Transverse Compression Device





Summary

- Three small-scale lab experiments have been developed to characterize fundamental effects of bending on single strands and transverse loads in multistrand cables
- Information will be used to understand fundamental issues of CICC
- Information could be used to estimate performance of ITER conductors but overall degradation has already been accounted for in design by scaling from CSMC and TFMC results.
- Experimental work is being supported by modeling and FEA analysis of non-linear composite conductors