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BENDING RADIUS LIMITS OF DIFFERENT COATED REBCO CONDUCTOR TAPES – AN EXPERIMENTAL INVESTIGATION WITH REGARD TO HTS UNDULATORS

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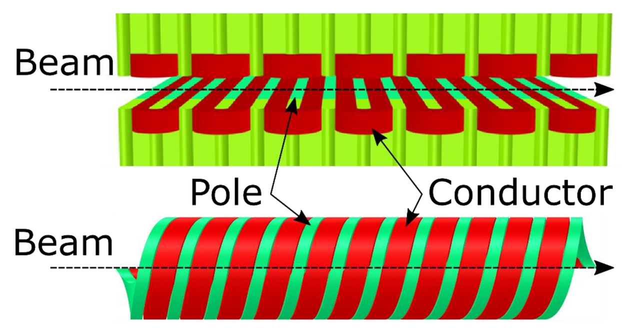
MOTIVATION

Advantages of employing high-temperature superconductors (HTS) to undulators for FELs and future lepton colliders (CLIC or FCC-ee):

- Facilitation of the operation compared to low-temperature superconductors, such as Nb-Ti or Nb_3Sn, due to broader temperature margins (up to ~90 K) and higher critical magnetic fields.
- Enhancement of undulator parameters: magnetic flux density amplitude for short undulator periods.



For short periods (< 15 mm), horizontal racetracks or helical undulators may require conductor bending radii smaller than 5 mm which will induce significant bending strain on the superconducting layer and may harm its conductance. Therefore we investigated coated REBCO tape conductors and their minimum bending radius.

EXPERIMENTAL METHODS AND SETUPS

- All bends were done under compression of the REBCO layer (inside, facing the winding body) for the best conductor performance [1].
- Imitating coil winding: Bend at room temperature, then cool down (77 K).
- Nanovoltmeter: Critical current I_c criterion of 100 µV/m while ramping I.
- Investigated bending radii: R = {10, 8, 7, 6, 5, 4, 3, 2.5, 1.25} mm.
- Two bending rigs were used, displayed in figure 1.
  - The Goldacker bending rig: investigation of reversible degradation and confirmation of measurements down to R = 5 mm [1], [2].
  - New designed U-bend rig: measurements of radii down to 1.25 mm with optional helical twist bend by using exchangeable, u-shaped bending bodies (c.f. figure 2). Support structures in combination with pressing the bending bodies on the conductor ensure a smooth fit.

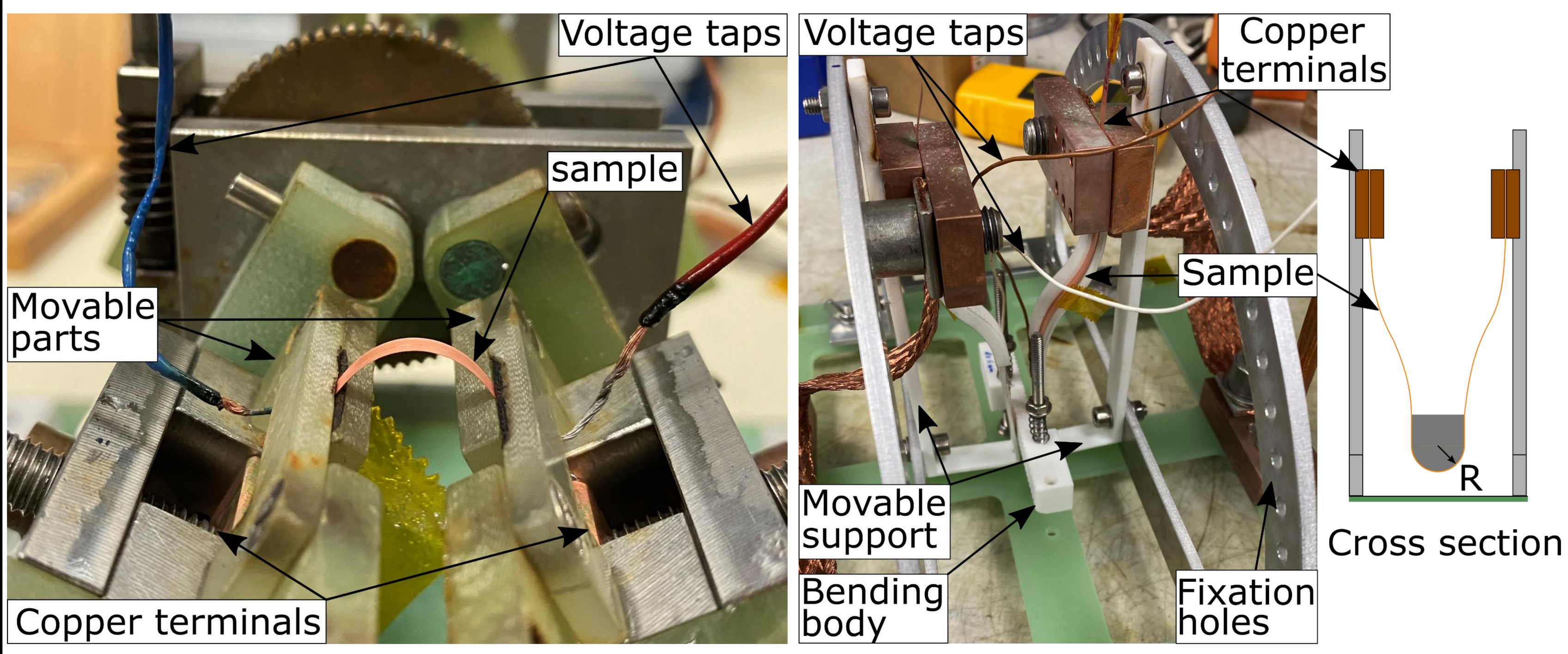
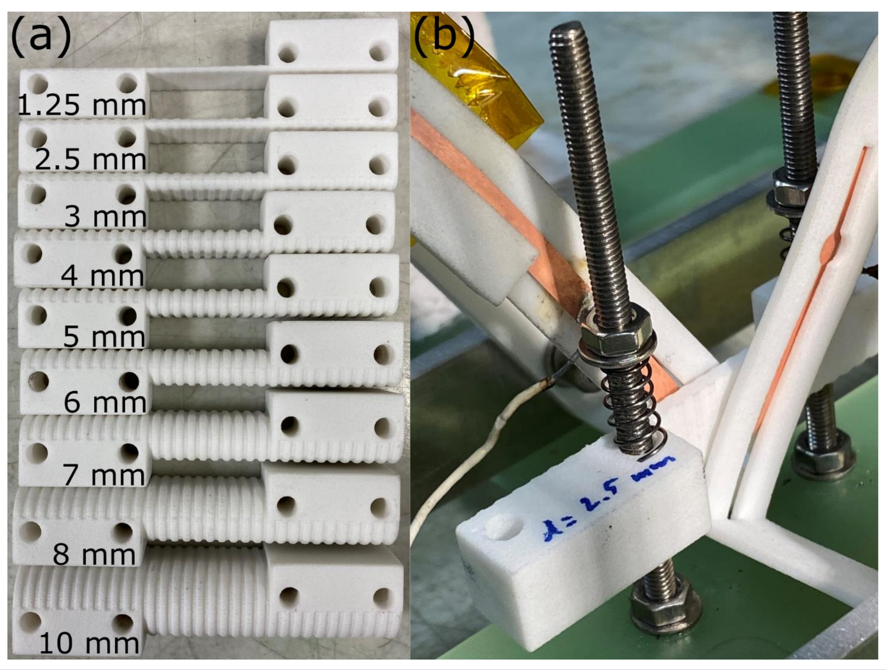


Figure 1: Close-ups of the used bending rigs. Left: "Goldacker" bending rig with a mechanically limited bending radius of 5 mm. Right: New designed "U-bend" rig for bending radii down to 1.25 mm and half helical twists.

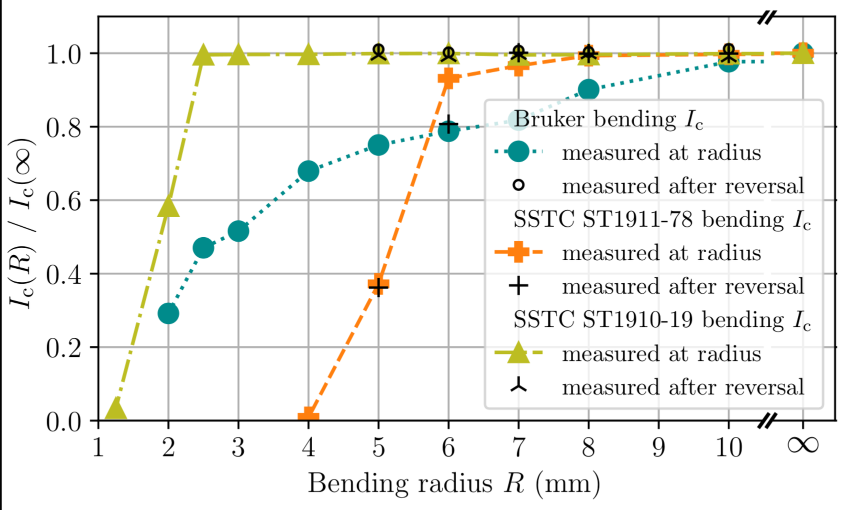
Figure 2: (a) displays used bending bodies with indicated radii. (b) shows a detailed view of a half helical twist bend for a 2.5 mm diameter and 30° configuration as well as the two nuts to apply pressure on the body via springs.

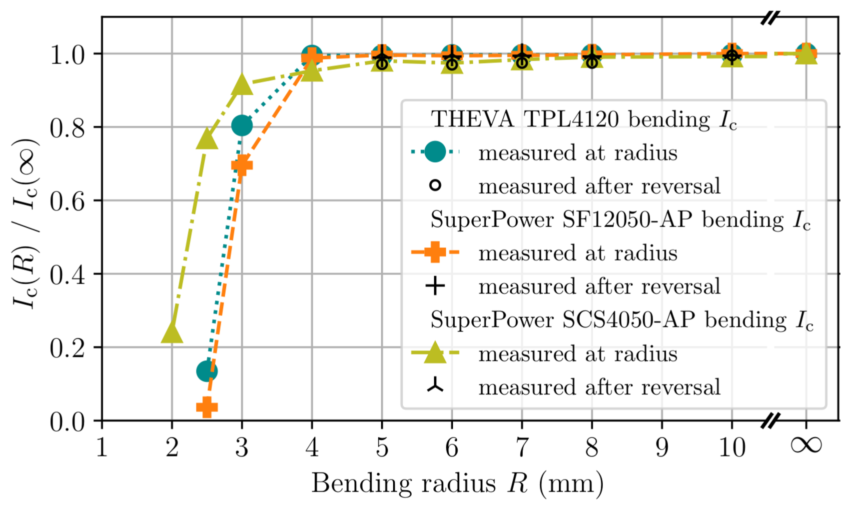


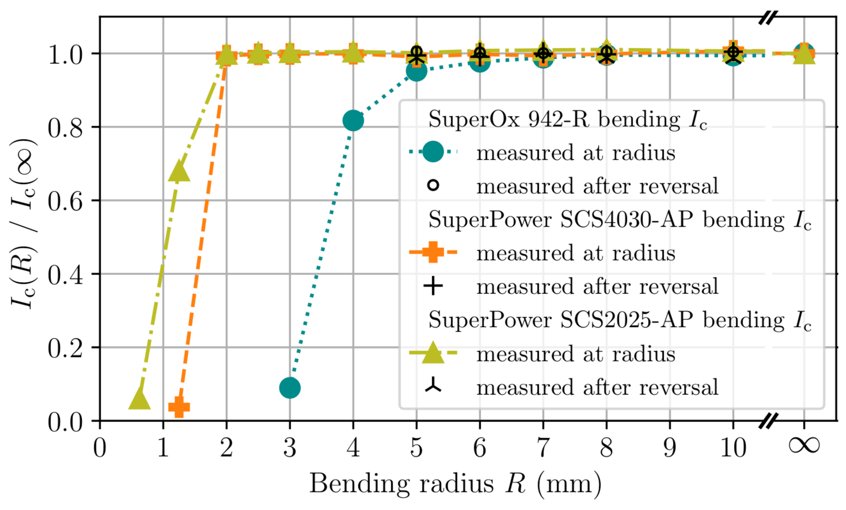
RESULTS

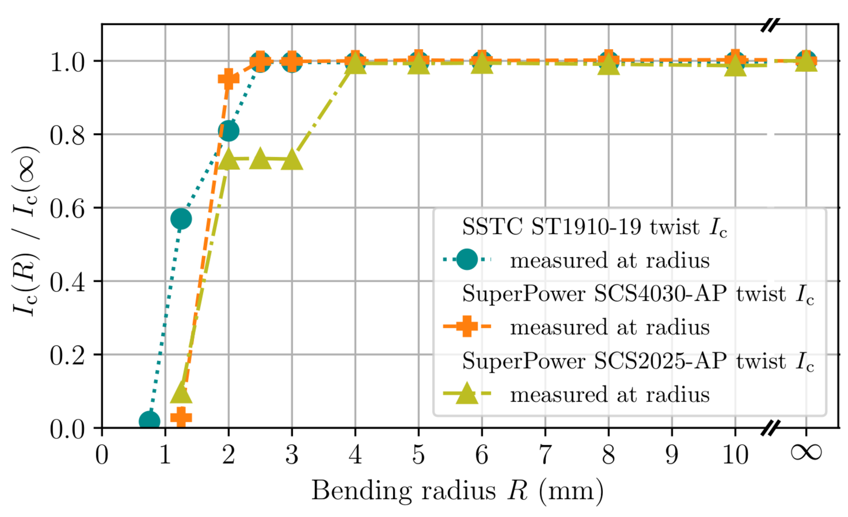
Table 1: Tested samples, their parameters, measured critical current I_c and measured minimum bending radius R_{min} when bent with the REBCO layer inside. R_{min} is defined as the smallest radius for which the measured critical current degrades less than 5% for normal bending.

Manufacturer	Reference	Tape width	Tape thickness	Substrate thickness	Measured I_c	R_{min}
THEVA	TPL4120	4 mm	80 µm	50 µm	167 A	4 mm
Bruker	–	4 mm	105 µm	50 µm	91 A	10 mm
ShanghaiSCT	ST19911-78	10 mm	95 µm	50 µm	360 A	7 mm
ShanghaiSCT	ST1910-19	4 mm	95 µm	50 µm	159 A	2.5 mm
SuperPower	SF12050-AP	12 mm	55 µm	50 µm	428 A	4 mm
SuperPower	SCS4050-AP	4 mm	100 µm	50 µm	135 A	4 mm
SuperPower	SCS4030-AP	4 mm	42 µm	30 µm	130 A	2 mm
SuperPower	SCS4025-AP	2 mm	36 µm	25 µm	65 A	2 mm
SuperOx	942-R	4 mm	76 µm	60 µm	127 A	5 mm









Bending:

- Besides SSTC ST1911-78 all samples showed no or reversible degradation down to R = 5 mm.
- SSTC tape behaved significantly different for different widths.
- The thinnest substrate conductors (30 µm and 25 µm) reached the smallest R_{min} = 2 mm.

Half twist bending (30°):

- SCS2025-AP degraded earlier than for normal bending.
- Same performance as normal bending for the other samples.

SUMMARY AND OUTLOOK

- Thinner substrate decreases the minimum bending radius. The tapes with the thinnest substrates (30 µm and 25 µm) reached the smallest R_{min} of 2 mm. However it still depends on the manufacturer and conductor type.
- Further investigations will include:
  - Complete helical bending (3 periods),
  - Strain linked to the bending radius concerning individual tape conductors.

REFERENCES

[1] S. Otten *et al.*, "Bending properties of different REBCO coated conductor tapes and Roebel cables at T = 77 K", Supercond. Sci. Technol. 29 (2016).

[2] W. Goldacker *et al.*, "Bending strain investigations on BSCCO(2223) tapes at 77 K applying a new bending technique", AIP Conf. Proc. 614 (2002).

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