



Flux Pinning Docking Interfaces in satellites using superconducting foams as trapped field magnets

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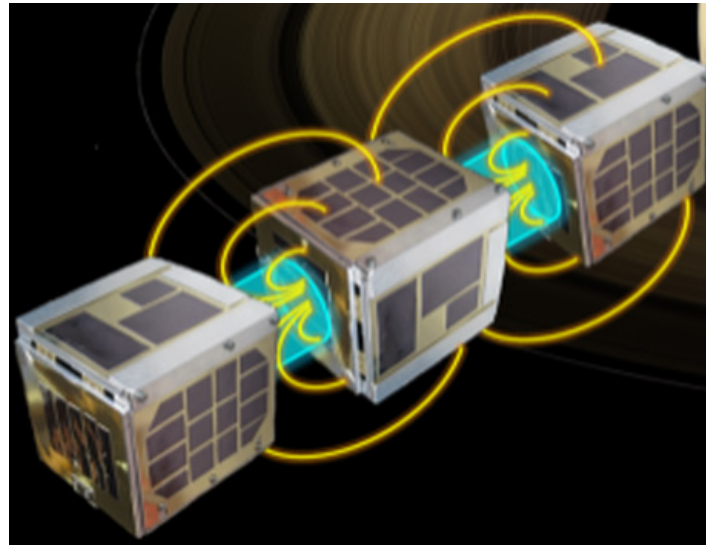
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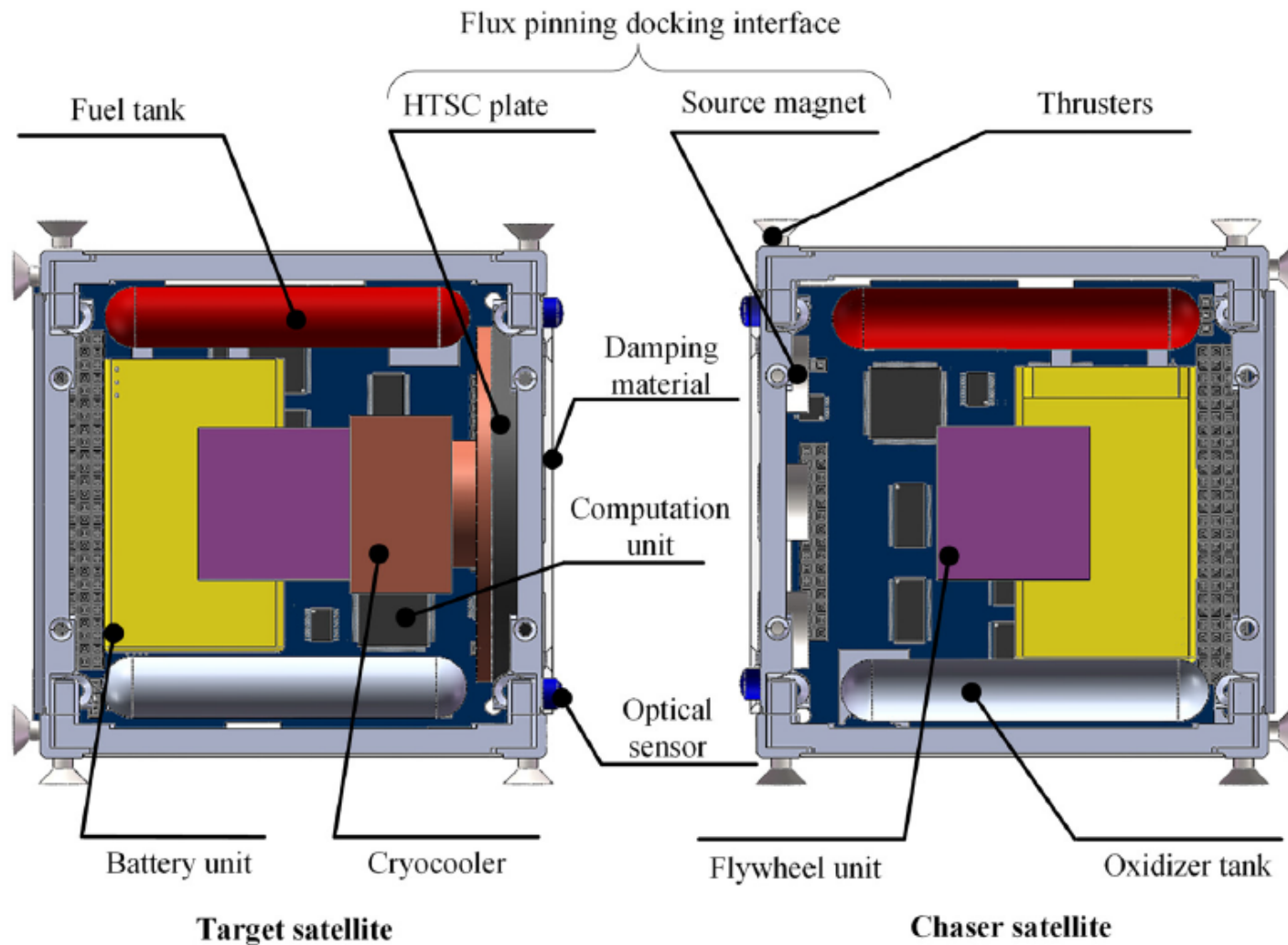




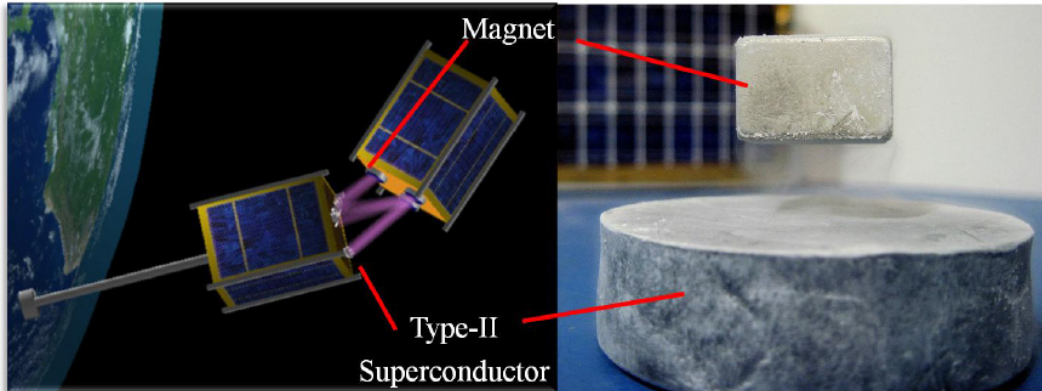
Flux pinning-coupled
cube sats in space

Flux-Pinning Docking Interfaces (FPDI) in satellite systems were developed using bulk superconductors and permanent magnets. However, such FPDIs have *limited* magnetic field strength, consist of *heavy-weight material*, and can only be used with a *single purpose*, i.e., as chasing or docking satellite.

Replacing the magnetic material in the FPDIs by a TF-magnet would enable the interface to operate for both purposes, i.e., generating a (stronger) magnetic field **and** trapping it. We show the requirements for such a system and discuss the possible gains when using a TF-FPDI in satellites. To reduce the system weight, the use of superconducting foams is discussed in detail.

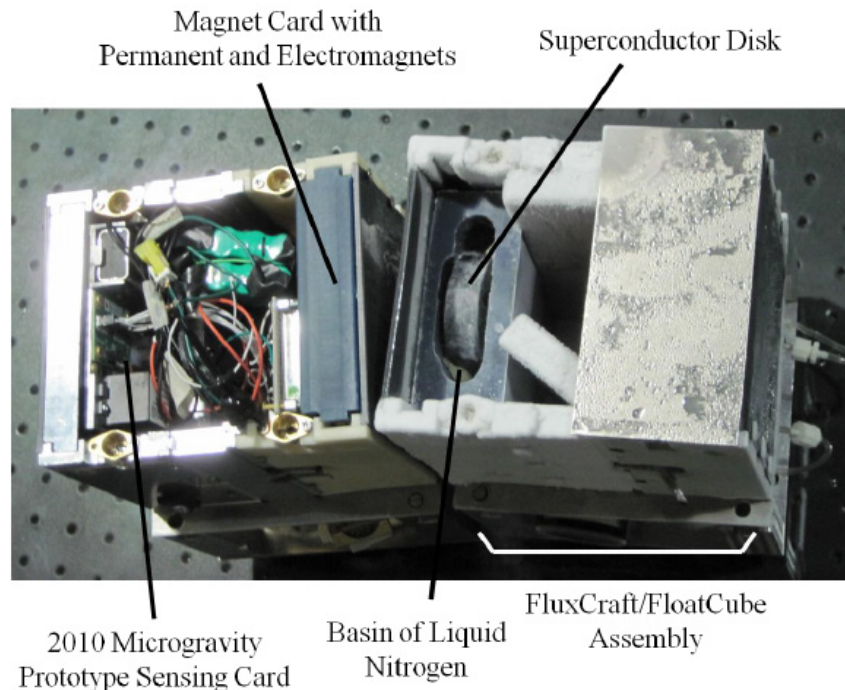
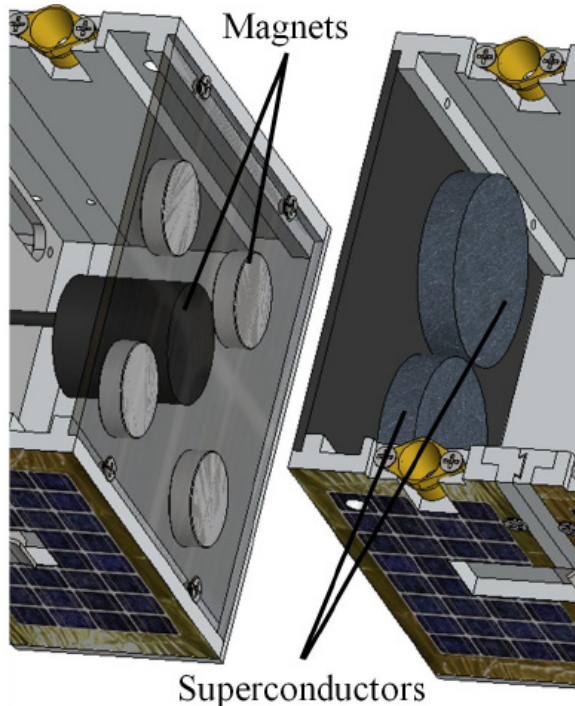


W. Yang *et al.*, JAP **124**, 213901 (2018)



Superconductor only used as the diamagnetic part to trap fields

difficulties to have large samples
 → for tests, several smaller samples were used

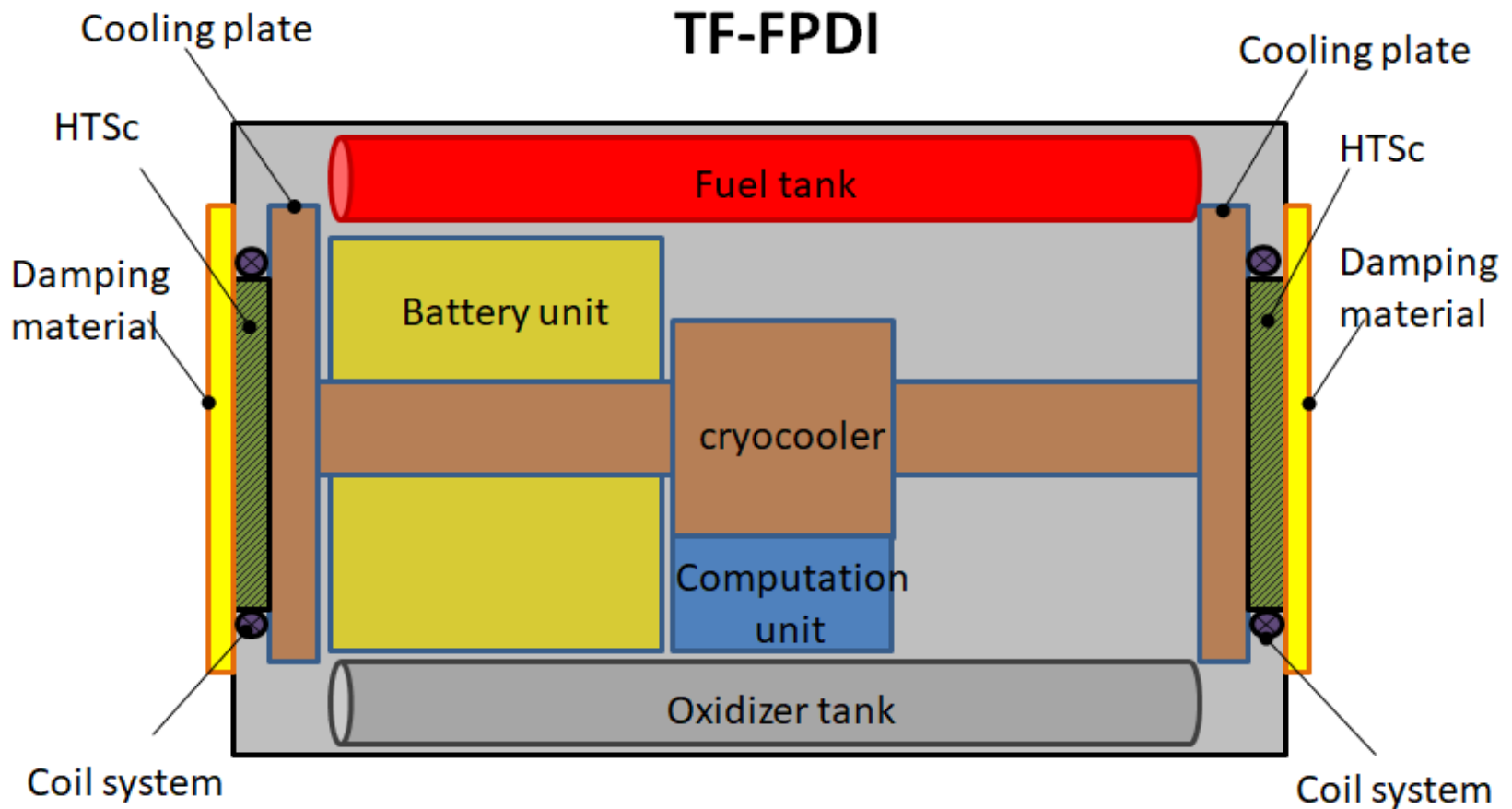


J. Shoer *et al.*,
 J. Spacecraft Rockets
47, 1066 (2010)

L.L.Jones,
 Thesis Cornell 2012



→ Using TF-principle, the satellite can be fully symmetric as the function can be chosen deliberately: **NO** distinction between *chaser* and *target* satellites necessary





Why use superconducting foams?

The foams may be applied as **ultra-light trapped field (TF) magnets** wherever the weight and the cooling efficiency counts, e.g., in space.

High cooling efficiency (coolant can pass through the sample, improved heat exchange).

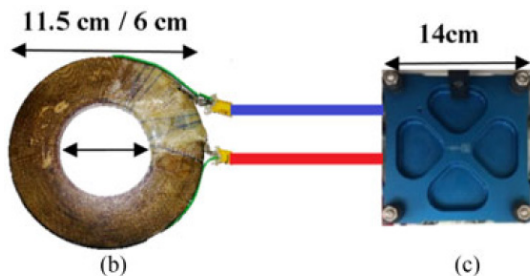
Straightforward **scalability of the sample size** (limited only by furnace size).

Foam material may also serve as **buffer material** (e.g., as **shock absorber** in the docking process)



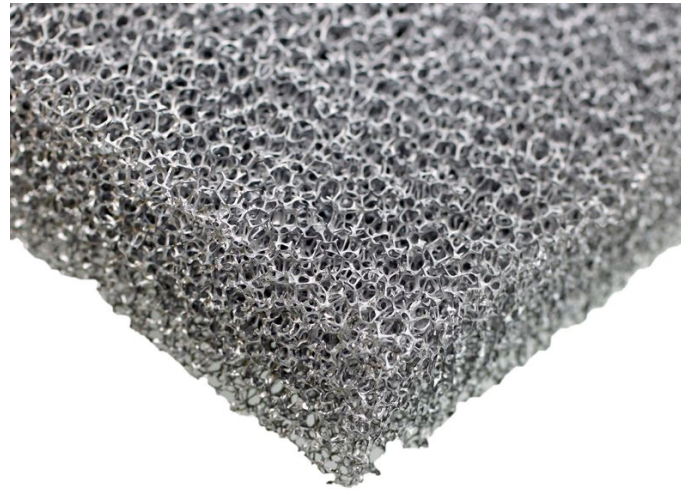
Advantages of the TF-FPDI

- # one common cryocooling unit for both superconductors
- # temperature can be lower than 77 K, e.g., 60 K or even 20 K
 - lower T will improve TF performance, eventually use of MgB_2
- # energizing by pulsed field technique
 - higher trapped fields as permanent magnets possible
 - saves weight (increases payload)
 - higher fields will improve the docking process, stability of system
- # energy for pulsed fields can be provided by a fuel cell system



M. Hinaje *et al.*, IEEE Trans. Appl. Supercond. **28**, 4202606 (2018).

PEMFC, 100 cm²

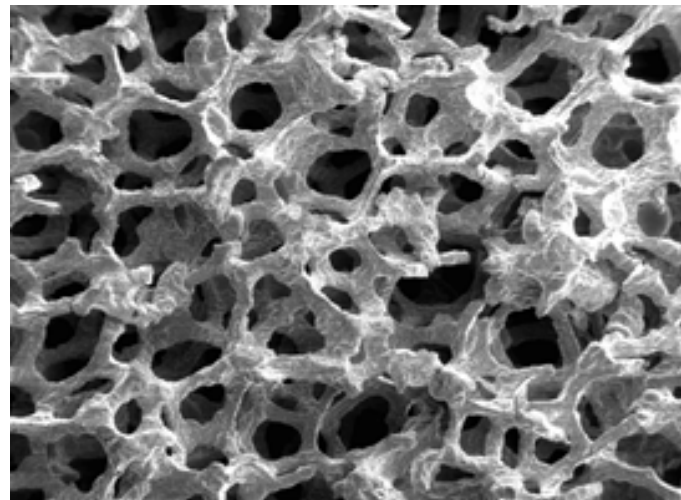


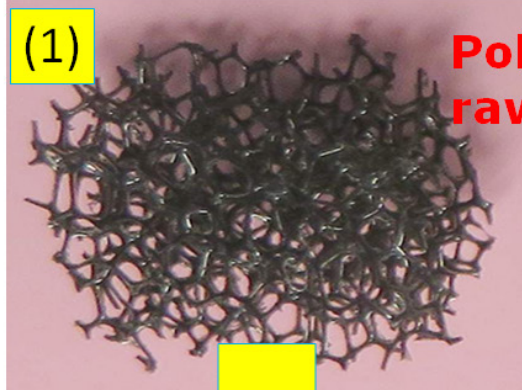
open-cell porous
metal foams

Al, Mg, Cu,....

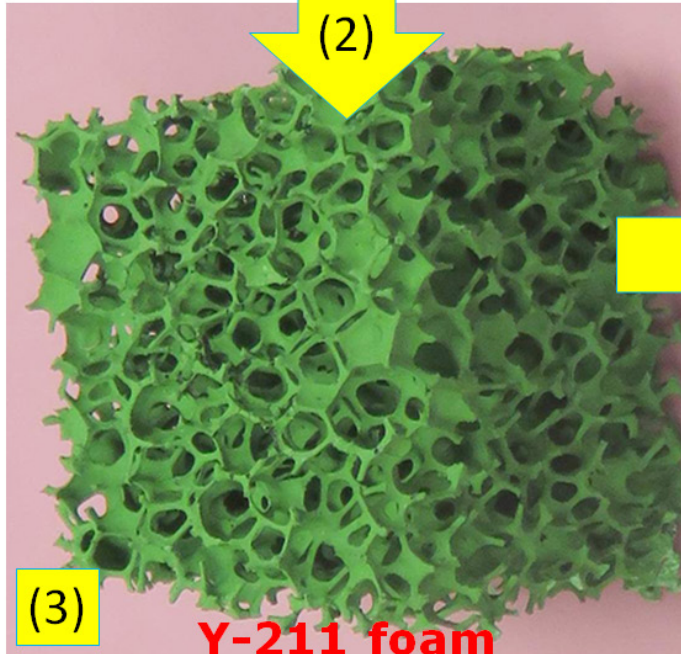
technical use as

- shock dampers
- heat exchangers





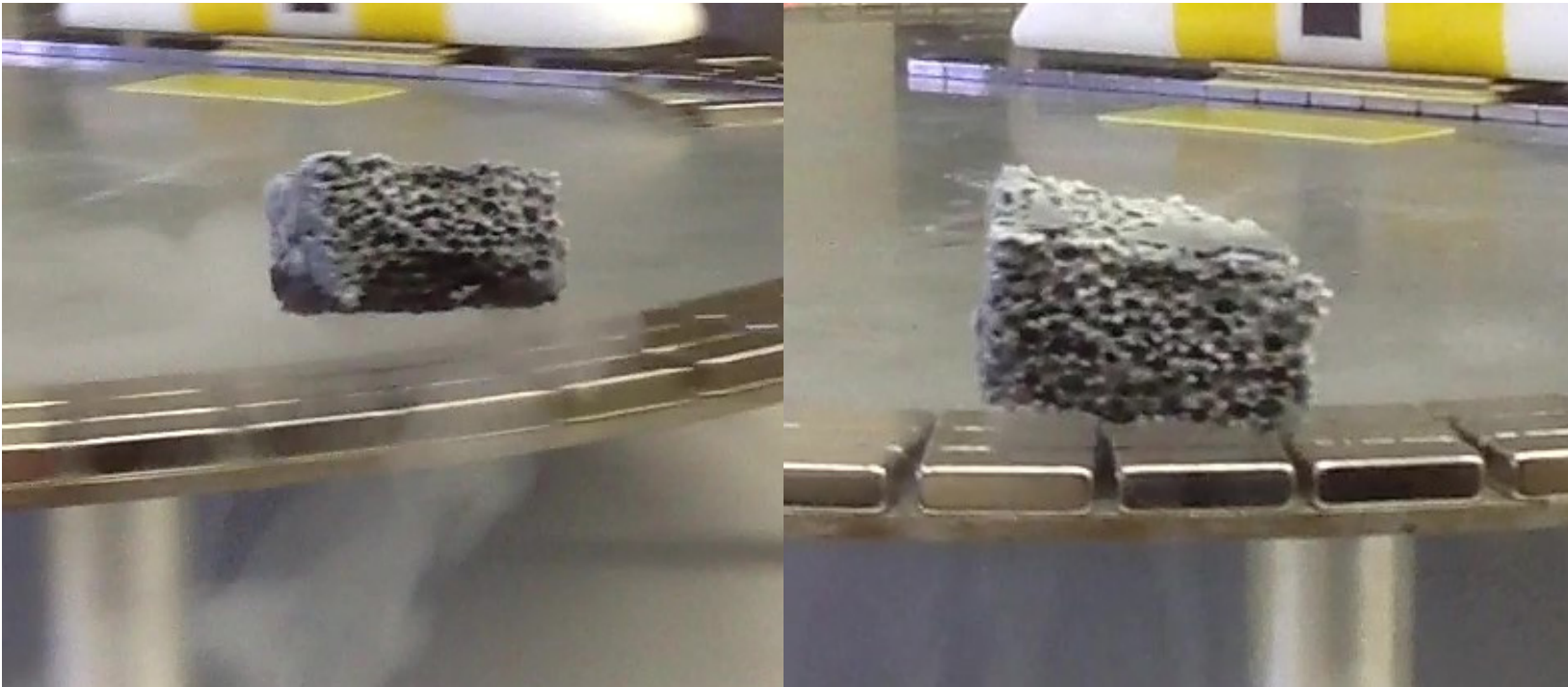
Polyurethane foam, raw material



(3) **Y-211 foam**

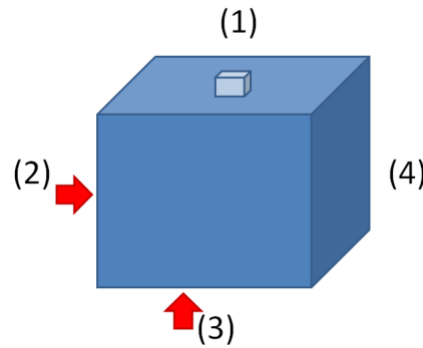
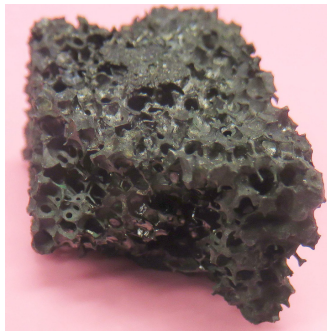


YBCO foam, 40 ppi



M. R. Koblischka *et al.*, *Materials* **12**, 853 (2019)

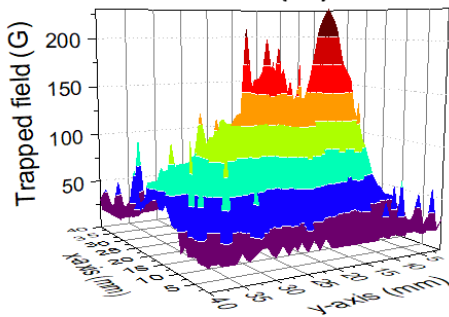
- high cooling efficiency
- reduced sample weight
- improved mechanical strength (cracking problem of large bulks)
- possibility for easy upscaling (large sample sizes possible)



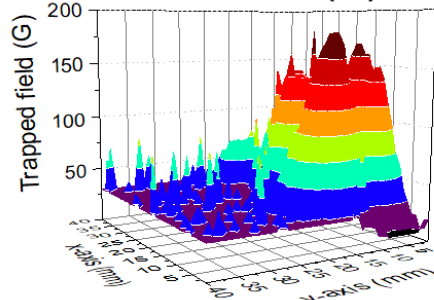
TF measurements on YBCO foams at 77 K

→ lower T as 77 K clearly useful
 → more work (2nd generation foams) required

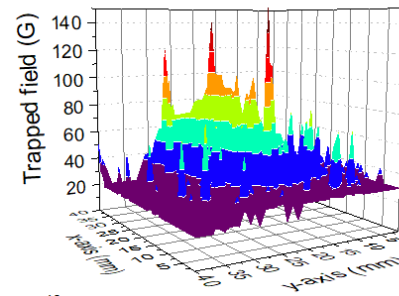
Side (1)



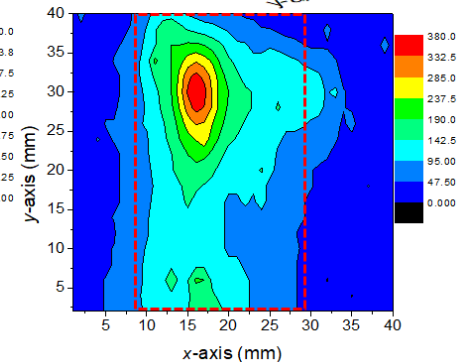
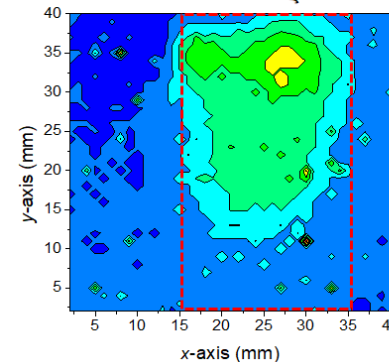
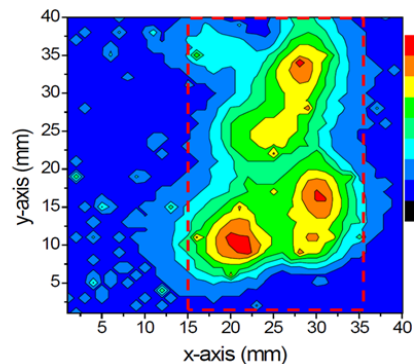
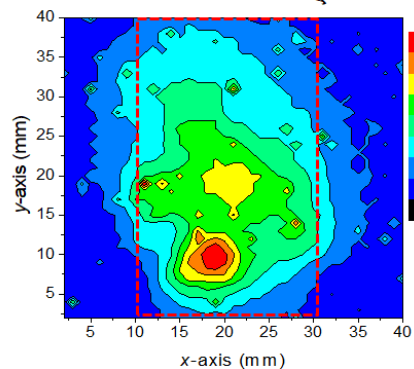
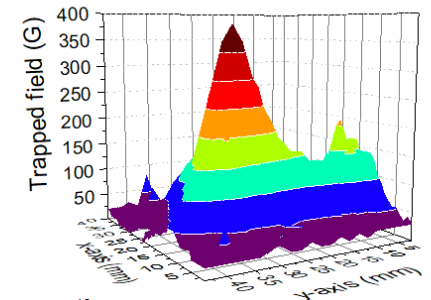
Side (2)



Side (3)



Side (4)





TF-FPDI enables

- **free use** of the coupling elements, satellites can be chaser AND targets on demand, more **complicated architectures** of satellite systems possible
- TF-magnets on board **save weight (increase payload)** by eliminating the heavy permanent magnets
- **easier docking** process with improved stability

Use of superconducting foams allows

- **larger sample sizes with further reduced weight**
- **combination of damping material and foam**

→ more work on foams required (larger sizes, multiseeding, **improved measurement conditions of large samples at lower T**)



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