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Progress in application of High Temperature Superconductor in Tokamak Magnets

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Abstract – It has long been known that high temperature superconductors **(HTS)** could have an important role to play in the future of tokamak fusion research. Here we report on first results of the use of HTS in a tokamak magnet (**GOLEM**, Czech Technical University at Prague) and on the progress in design and construction of the first fully-HTS tokamak (**ST25**, Culham Science Centre).

Introduction

• In 2011, **Tokamak Solutions** and **Oxford Instruments**, in collaboration with the Czech Technical University in Prague, carried out the first successful tests of an HTS coil on a tokamak. In the experiments, two of the copper poloidal field (PF) coils on the Golem tokamak in Prague were replaced with a pair of liquid nitrogen cooled coils each of 6 turns of HTS (RE)BCO tape material manufactured by SuperPower (US).

• Like traditional low temperature superconductors, HTS conduct current with zero electrical resistance so that coils can be run without any resistive heating. Although superconductivity in HTS is achieved at liquid nitrogen temperatures, remarkable further improvement in performance is achievable at lower temperatures. **HTS promises much better performance** in all the main characteristics of importance for application in tokamak magnets: **higher fields, higher critical current, better irradiation resilience**.

Bench tests and no-plasma tests of HTS

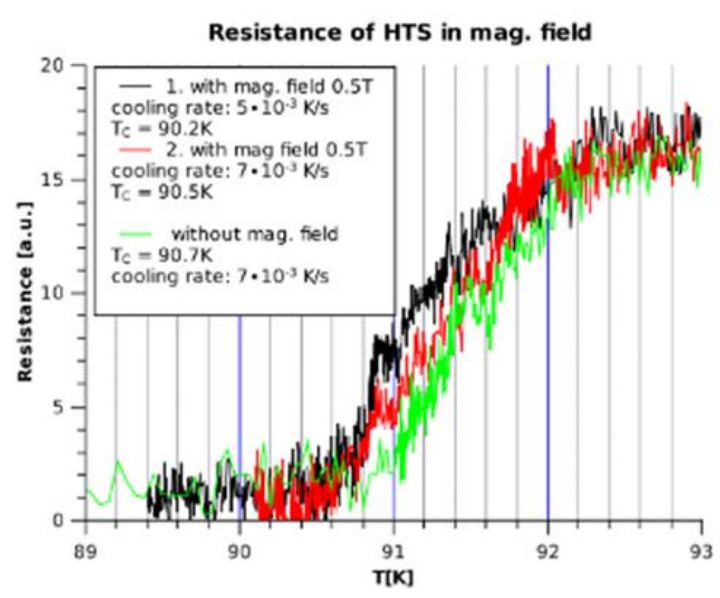

Fig.1. Superconductivity achieved at 91K with zero, or 0.5T external field

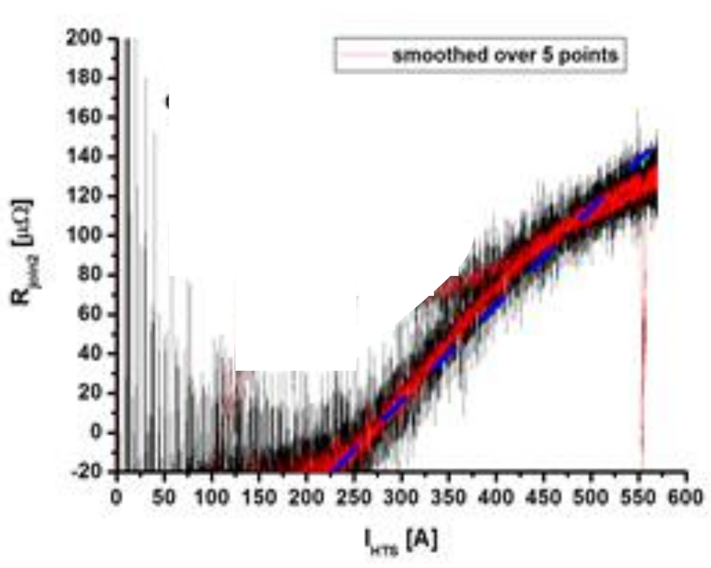

Fig.2. Resistivity over a soldered joint within one coil, i.e. with 40mk of Cu layer between HTS layers. Critical current of this tape ~330A

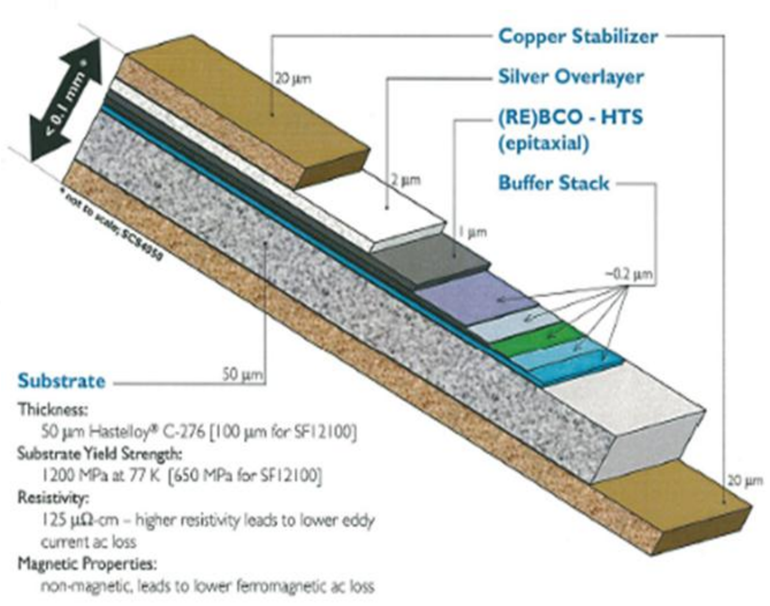

Fig.3. Structure of the (RE)BCO tape manufactured by SuperPower (US), used on GOLEM

Fig.4. left – maximum current in the coil 5.4kA (**840A** through the tape), which is 2.5 times higher than I_{crit} specification;
right – current ramp-up speed ~ 100kA/s

• **No degradation at these extreme loads**

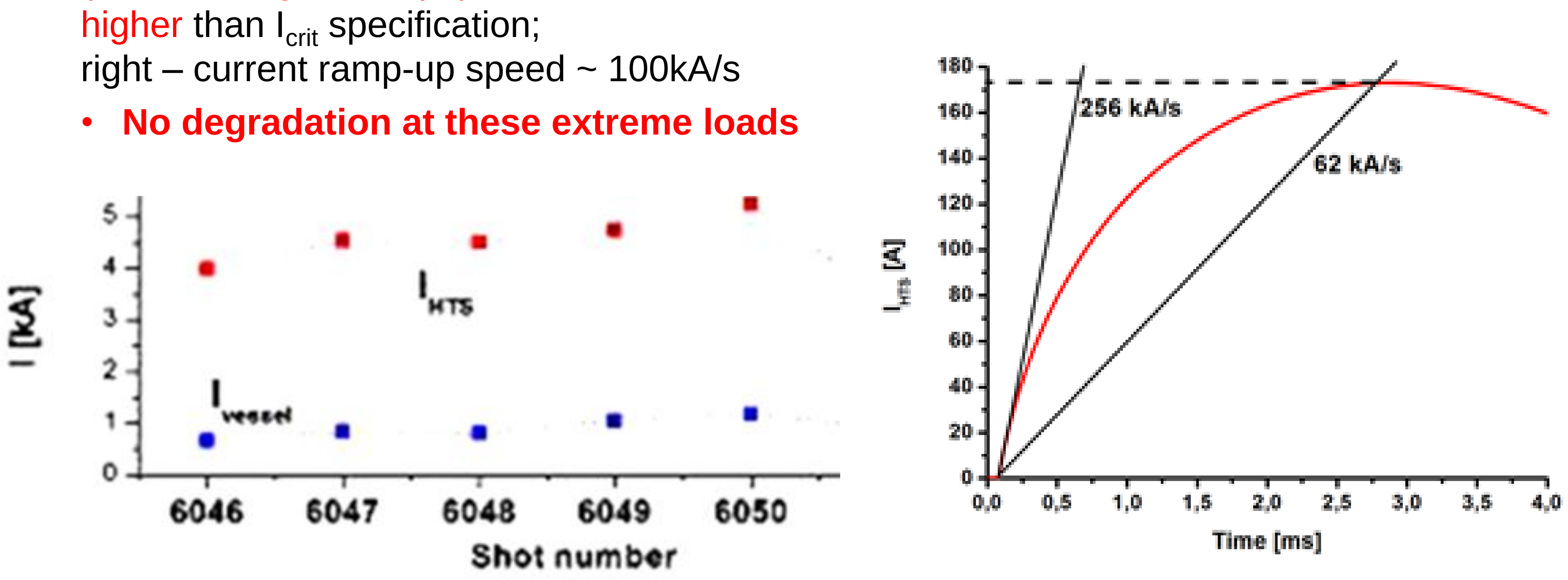

Fig.5*:* left - Tokamak GOLEM with two HTS PF coils; right - plasma pulse

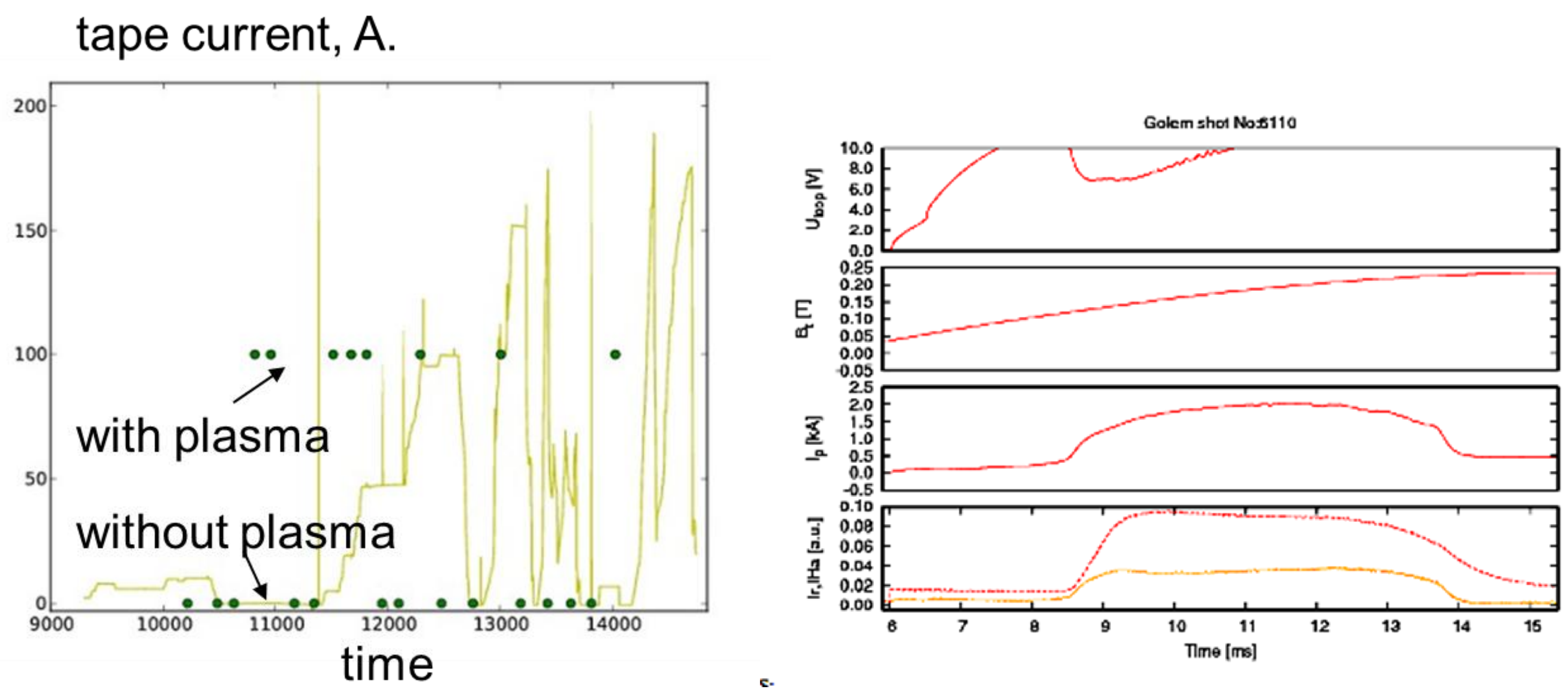

Fig.6*:* left - Many pulses have been performed with and without plasma; right – traces of a typical 2kA plasma pulse on Golem with two HTS PF coils;

- **Successful tests of HTS coils on GOLEM** provided enough confidence to design and start construction of the first **full-HTS tokamak, ST25**.
- ST25 main parameters:
  R/a = 25/12.5cm
  B_t = 0.1 - 1 T
  I_{pl}= 5-20 kA
  pulse duration: Cu coils 1 – 5 s
  HTS coils: s/state
  current drive: EBW 3 – 20kW
  wall conditioning: Li
  divertor/limiter: liquid Li

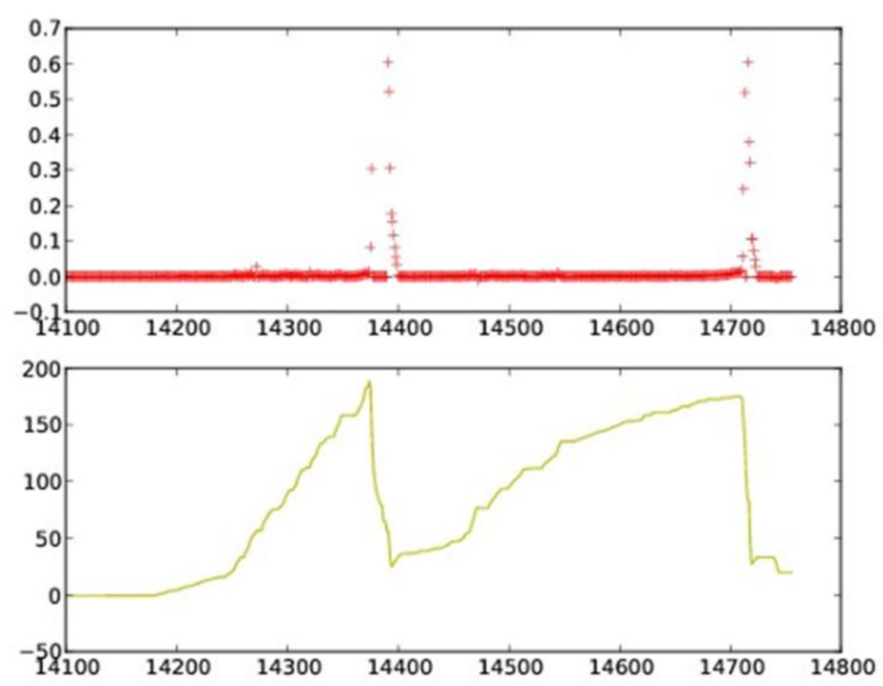

Fig.7. No HTS degradation observed after a quench: top – voltage, bottom – current in HTS tape.

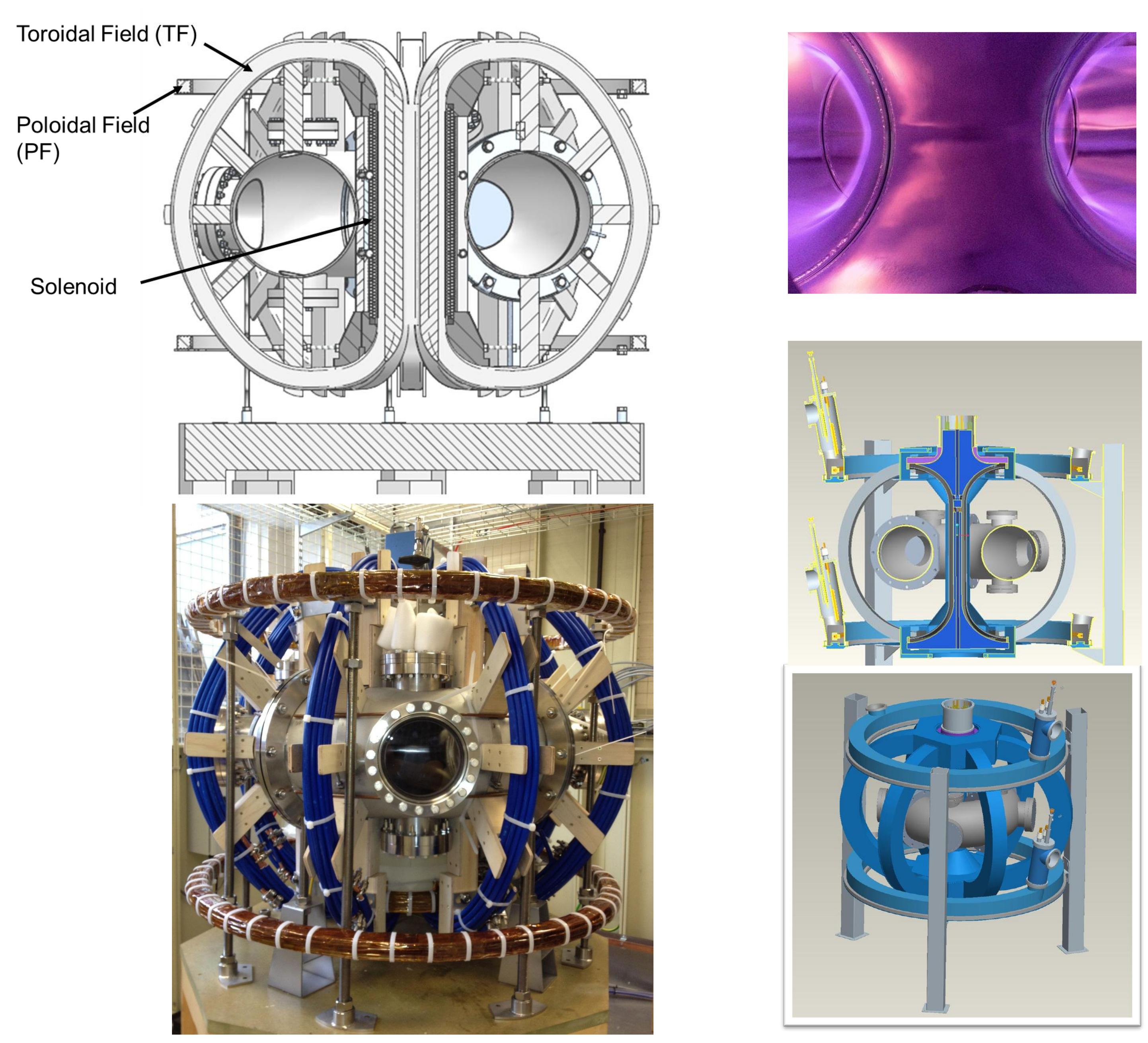

Fig.8: ST25: present status (Cu magnets) with glow-cleaning discharge in argon; and full-HTS design (commissioning December 2012)

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