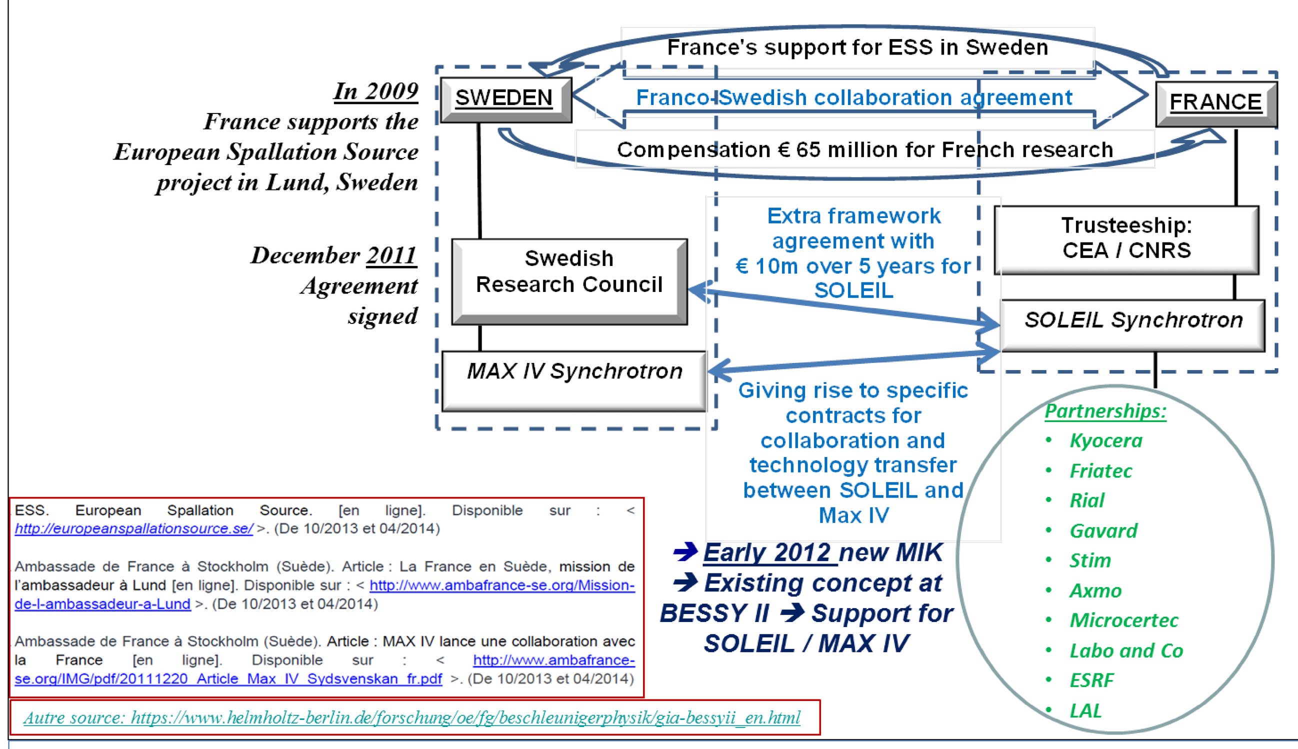
MULTIPOLE INJECTION KICKER (MIK) A COOPERATIVE PROJECT SOLEIL AND MAX IV

J. Da Silva Castro, P. Alexandre, R. Ben El Fekih, S. Thoraud, Synchrotron SOLEIL, 91190 Gif-sur-Yvette, France

Background : The cooperative MIK project SOLEIL / MAX IV started in 2012 and is part of the Franco-Swedish scientific collaboration agreement, signed in 2009 and followed by framework agreements signed in 2011. The MIK is a particular electromagnet using theoretical principles of the 1950s and recently used by the new generation of synchrotrons to significantly improve the Top-Up injection of electrons into the storage rings. Indeed, this type of magnet can drastically reduce disturbances on stored beams and also offers substantial space savings. The MIK is a real opportunity for synchrotrons wishing to upgrade their facilities. One of the first MIK developed by BESSY II in 2010 gave significant results. These results motivated SOLEIL and MAX IV to develop together their own MIK. Many technical challenges have been overcome in the area of mechanical design and manufacture as well as in magnetic and high voltage design of the MIK. Currently the first series is in operation at MAX IV and displays already outstanding performances. Optimization work is in progress.

(Franco-Swedish collaboration: Diagram of José da Silva Castro)



ESS. European Spallation Source. [en ligne]. Disponible sur : < http://europeanspallationsource.se/ >. (De 10/2013 et 04/2014)

Ambassade de France à Stockholm (Suède). Article : La France en Suède, mission de l'ambassadeur à Lund [en ligne]. Disponible sur : < http://www.ambafrance-se.org/Mission-de-l-ambassadeur-a-Lund >. (De 10/2013 et 04/2014)

Ambassade de France à Stockholm (Suède). Article : MAX IV lance une collaboration avec la France [en ligne]. Disponible sur : < http://www.ambafrance-se.org/IMG/pdf/20111220_Article_Max_IV_Sydsvenskan_fr.pdf >. (De 10/2013 et 04/2014)

Autre source: https://www.helmholtz-berlin.de/forschung/oe/fg/beschleunigerphysik/gia-bessyii_en.html

Partnerships

- Coorstek ➔ Ceramic Chambers prototype
- Friatec ➔ Ceramics Chambers
- Kyocera ➔ Sapphire Chambers
- Rial ➔ Special Flanges with bellows and RF contacts for chambers
- Gavard ➔ MIK mechanics, frames and assembly tools
- Stim ➔ Mechanical magnetic measurement bench and tools
- Axmo ➔ Magnetic measurement bench motors/guides for probe displacement
- Microcertec ➔ Magnetic measurement bench probe
- Labo and Co ➔ Curing oven (coil annealing treatment, glue polymerization)
- ESRF ➔ Titanium coating inside chamber (for image current flow)
- LAL ➔ Three-dimensional controls of the chambers

Global investment: ~ 800 k €, financed by the Swedish Ministry of Research (P. ALEXANDRE)

Development and realization of vacuum chambers / electromagnets	300 k€
Development and realization of pulsers	156 k€
Development and realization of the command control	34 k€
Mechanics of electromagnets & assembling tools of Chambers	116 k€
Magnetic measurement bench	30 k€
Staff (excluding SOLEIL & MAX-IV): Concept 21 & Axileo	150 k€

Some dates……….

- Early 2012
  - Beginning of the SOLEIL / MAX IV collaboration
- 2013
  - First draft of mechanical design & concept
  - R & D and 1st prototyping & feasibility of chamber with Coorstek
- 2014
  - 1st technical consultation of KYOCERA for chambers/magnets
  - High voltage pulser studies
- 2015
  - Order to KYOCERA for 4 chambers
  - Tooling & assembly studies start
- 2016
  - Order flange welding tools, coils folding and gluing tools
  - Order FRIATEC for 2 chambers
  - Order mechanical parts / frames for 2 magnets
- 2016/2017
  - Magnetic measuring bench: studies / supplies / assembly, tests
  - Tools tests and final assembly of 1st MIK for MAX IV
- 08/2017
  - Installation at MAX IV
- Sept. 2017
  - Commissioning at MAX IV (Storage ring 3 GeV)
- Nov. 25th, 2017
  - First injection with a prototype MIK at MAX IV
  - Excellent performances after machine & magnet tuning
- Current status :
  - Investigations of coating thickness and heating issues
  - Magnetic measurement bench characterization
  - Assembly of the 4 definitive magnet

Acknowledgements:

A special tribute to a friend, Pierre Lebasque, who just left us
He was the project manager for the MIK at Soleil,
The team leader of Pulsed magnets group of Soleil for many years,
And I had collaborated for 15 years on different projects with him.

SOLEIL (Gif-sur-Yvette)

Pulsed magnets :
- P. Alexandre, R. Ben El Fekih, A.Letrésor, A. Hardy (ret), D. Muller, M. Bol.

Mechanical Engineering :
- J.L. Marlats (ret), J. Da Silva Castro, S. Thoraud, N. Jobert , F. Lepage, P. Prout, C. De Olivera, C. Basset (ret), S. Bonnin. S. Genix (Concept 21)

Vacuum :
- C. Herbeaux, N. Béchu, S. Morand, N. Baron, V. Joyet.

Electronics & Computer Control :
- G. Renaud, P. Monteiro, X. Elattoui, T. Jablonka.

Metrology and alignment :
- A. Lestrade, C. Bourgoin.

Accelerator physics :
- R. Nagaoka, A. Loulergue.

Purchase & Juridical :
- T. Bucaille, F. Minaeian, E. Monin.

Collaborations : N. Guimard.

General project leadership
P. Lebasque(SOLEIL)
P. Fernandes Tavares (MAX-IV)

MAX-IV (Lund)
E. Al d'Mour, J. Ahlbäck, S. Leeman, M. Johansson, L. Dallin, B. Jenssen, K. Ahnberg , M. Grabski, M. Gunnarsson , V. Hardion, J. Thanel, J. Jamroz.

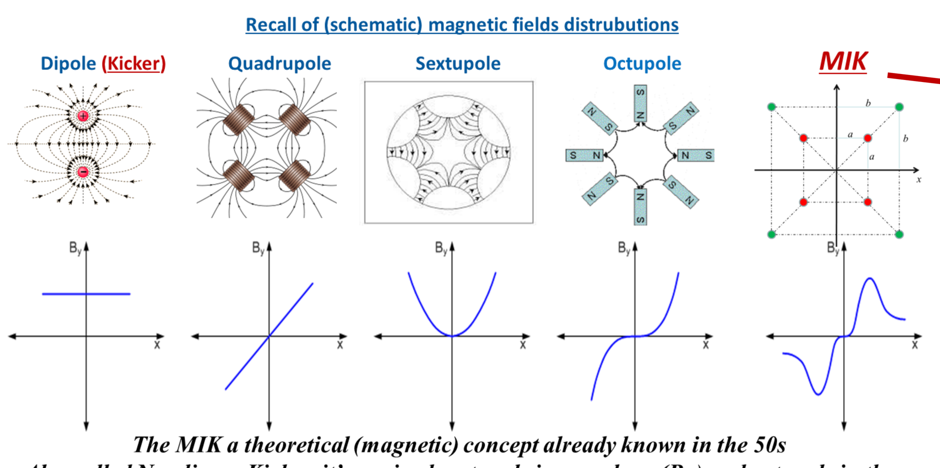
BESSY II (Berlin)
O. Dressler, P. Kuske.

LAL (Orsay)
B. Leluan.

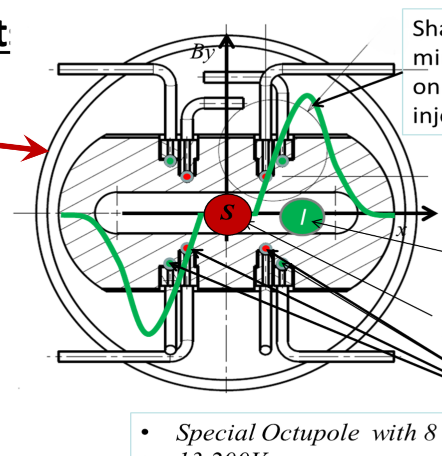
ESRF (Grenoble)
M. Dubrulle et H. Marques.

General description: The MIK is composed of a chamber in two part of synthetic monocrystalline Sapphire. Parts are assembled by diffusion bonding (Kyocera Japan). Chamber can also be made in alumina with two parts assembled by glass gluing or brazing depending on the subcontractor (Friatec or Coorstek). The chamber has to be machined with a very high precision to ensure a good magnet. 8 grooves positioning the 8 conductors (copper) are machined in the hundredth of a millimeter. The conductors formed and there insulating bars (alumina) are glued in the grooves, with specific tools designed and used by Soleil team. The connection between the chamber and the flanges is ensured by a brazed Sapphire/copper interface, then a brazed copper/ stainless steel interface and finally a stainless steel / flange weld. A titanium coating of a few microns inside the sapphire vacuum chamber (made at ESRF) allows the flow of the image current without disturbing the magnetic field.

Principles and interest



The MIK a theoretical (magnetic) concept already known in the 50s
Also called Non linear Kicker, it's a mixed sextupole in one plane (Bx) and octupole in the other plane (By)
PURPOSE OF THE LAST YEARS TO IMPROVE INJECTION IN THE STORAGE RING
Sources: O. Dressler, P. Kuske - USR Workshop, Huairou, Beijing, Oct. 30 - Nov. 1, 2012



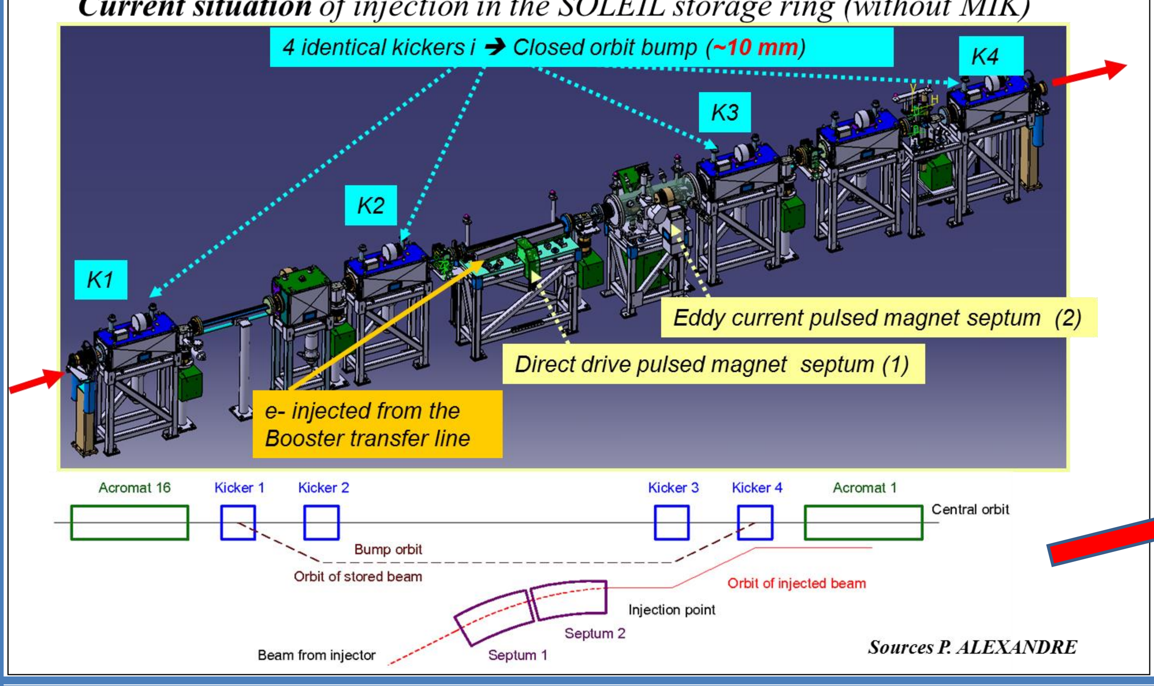
Shape of transversal magnetic field (By(x)) to minimise effects on Circulating electron beam on the center (S). Only electron beam to be injected (I) sees a significant magnetic field.

(Cross-sectional view and principals of the MIK)
(I) Injected electrons beam
(S) Circulating electrons beam on storage ring

- *Special Octupole with 8 copper conductor, diameter 2 mm, in series*
- *13 200V*
- *Half-sine current pulse 7700 peak Amps*

➔ MIK injects the electron beam without KICKERS ➔ No closed bump of the orbit of the stored beam (S)
➔ Few oscillations of (S)

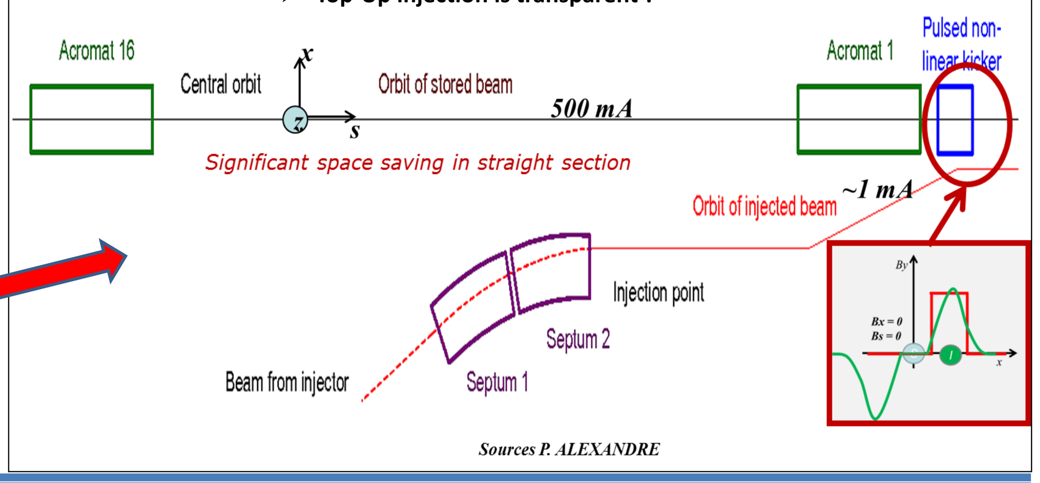
***Current situation** of injection in the SOLEIL storage ring (without MIK)*



Sources P. ALEXANDRE

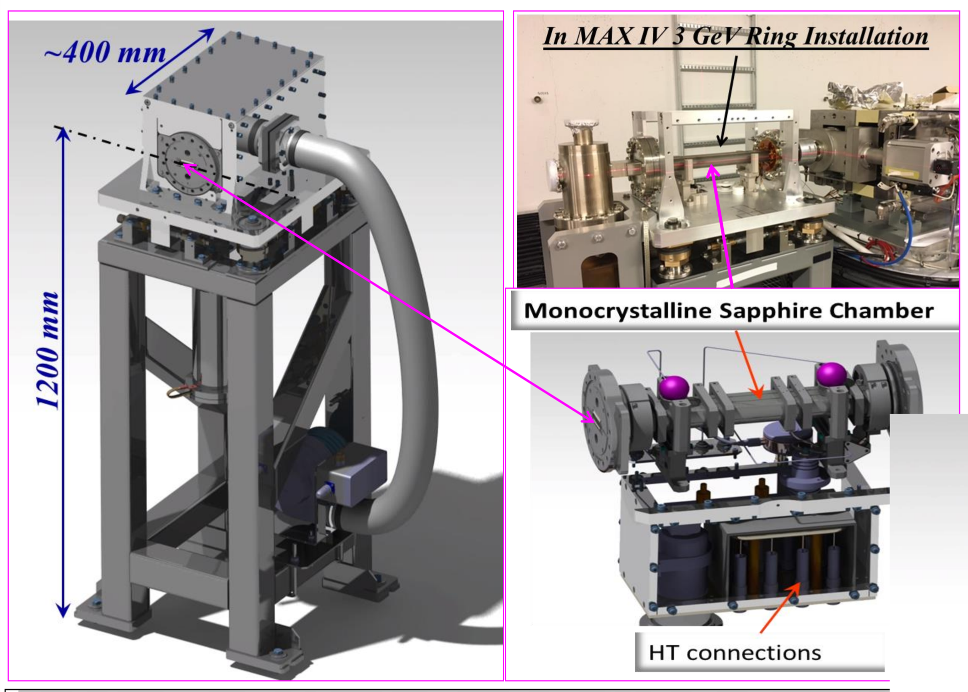
Target with MIK: Inject without disturbing the beam of the storage ring (S)

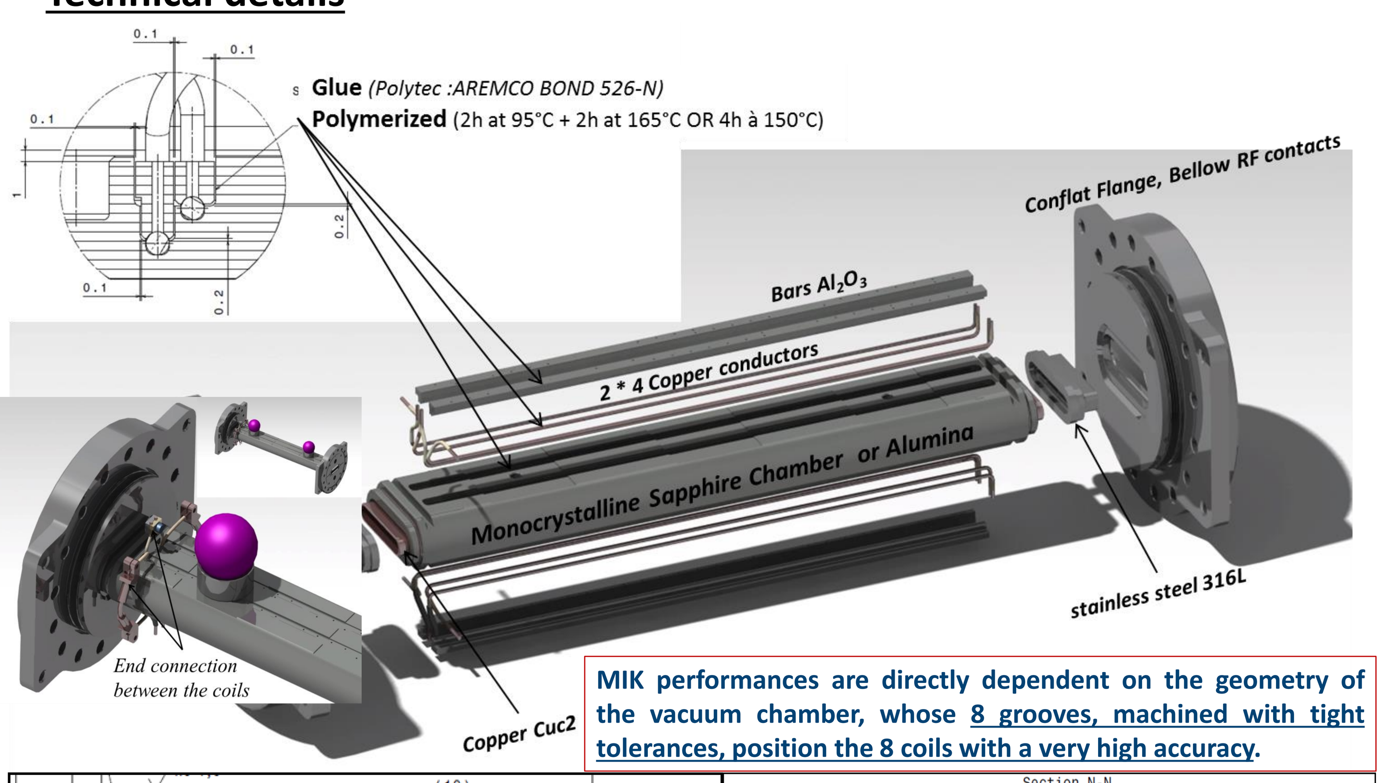
- Significant By field off-axis (S) to kick injected electron beam.
- B = 0 on axis : Stored beam does not oscillate.
- The injected beam (~1 mA) damps turn after turn into the stored beam.
- Beam oscillation seen by beamlines is virtually non existent.
  - Top-Up injection is transparent !



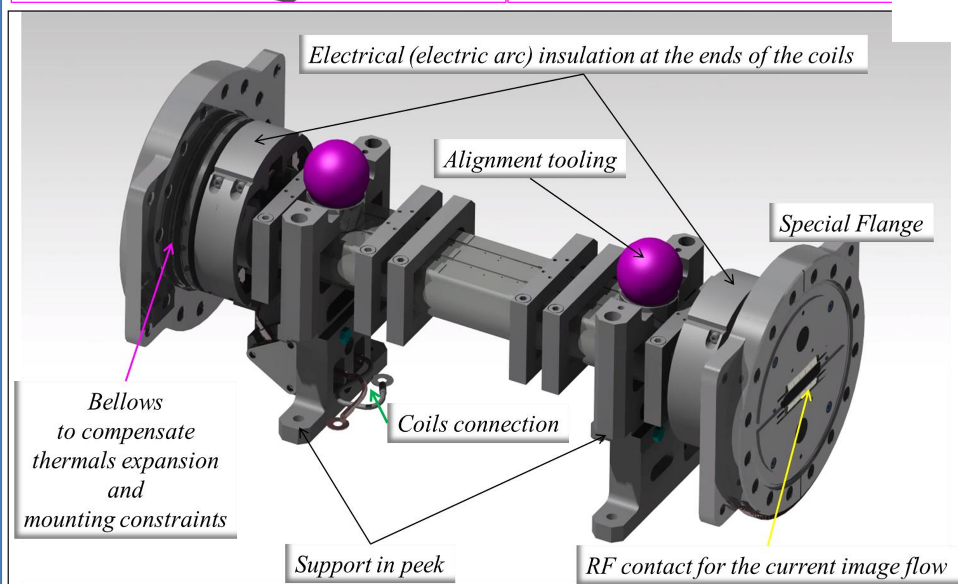
Sources P. ALEXANDRE

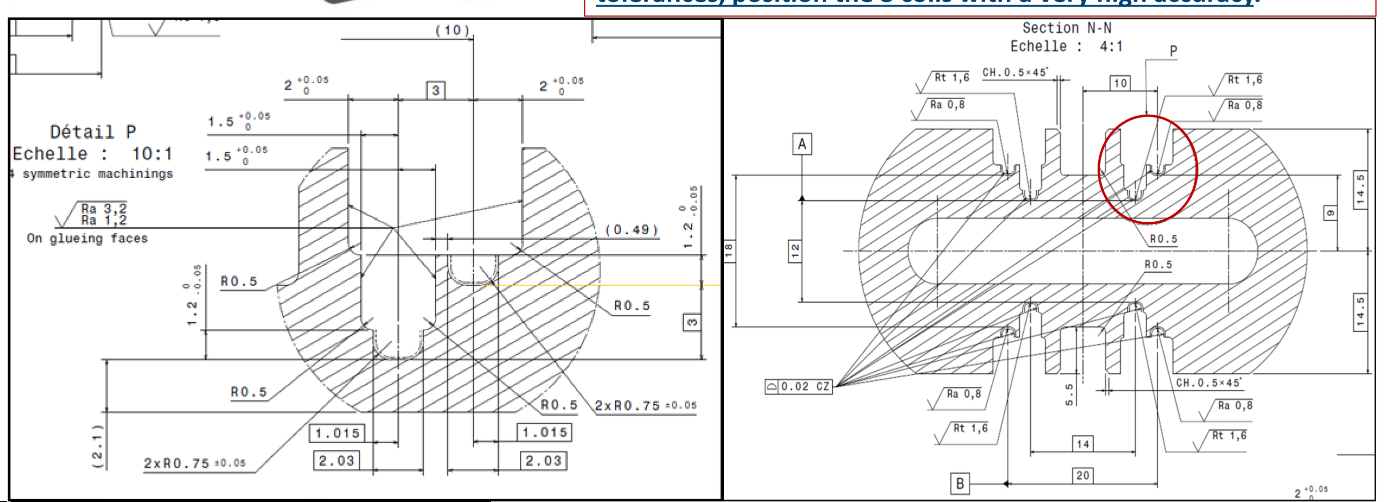
Technical details



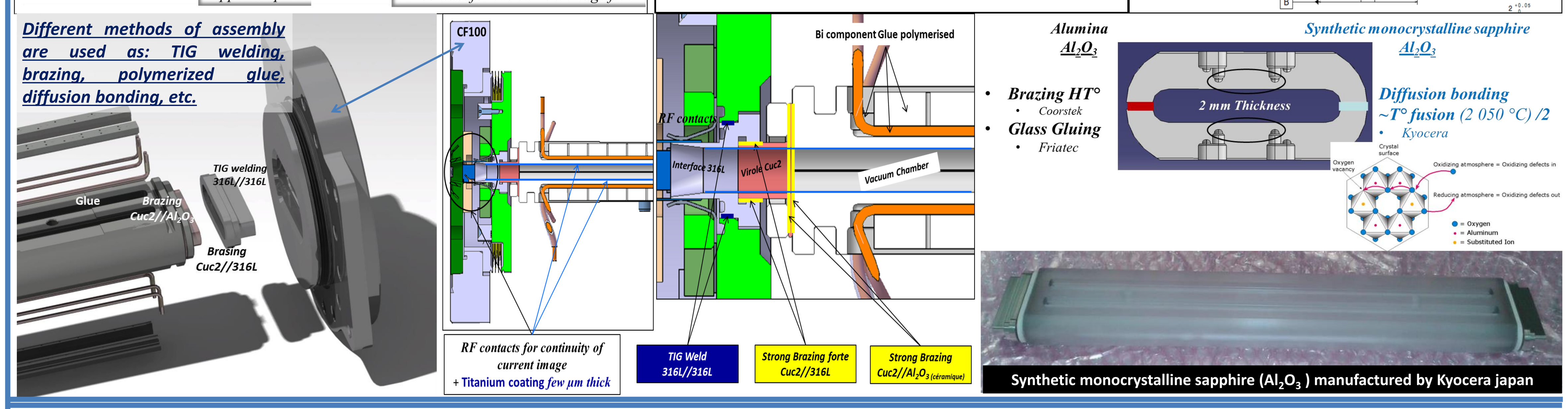


MIK performances are directly dependent on the geometry of the vacuum chamber, whose 8 grooves, machined with tight tolerances, position the 8 coils with a very high accuracy.

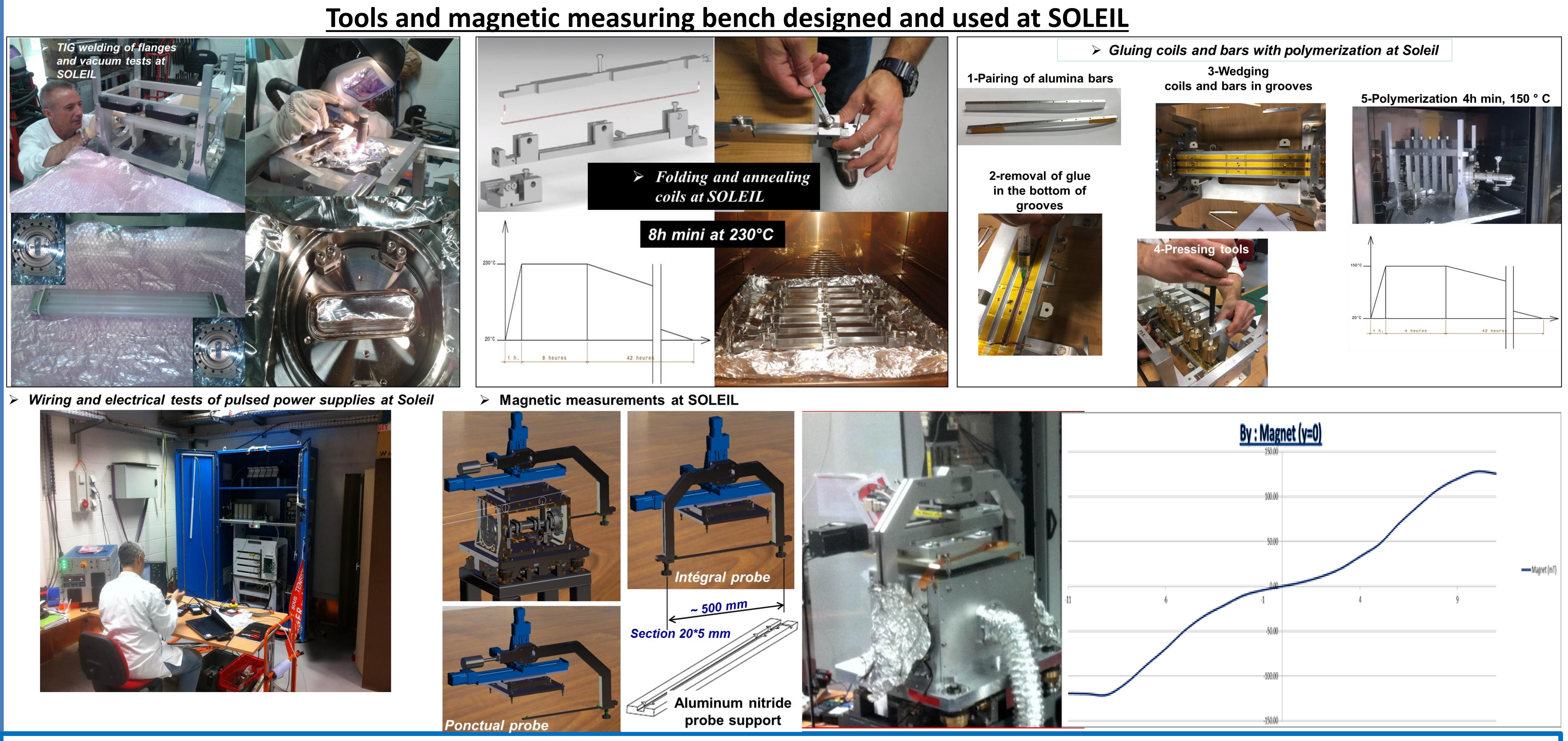




Different methods of assembly are used as: TIG welding, brazing, polymerized glue, diffusion bonding, etc.



Tools and magnetic measuring bench designed and used at SOLEIL



Conclusions: MIK is a good example of collaborative project involving many partners. This particular electromagnet is an opportunity for the new generation of synchrotrons by reducing drastically disturbances on stored beams during top up injection, and also offers substantial space savings. Technical challenges have been overcome and a great know-how has been acquired. In MAX IV, the first MIK shows already remarkable performances that can still be optimized.