Static and transient magnetic design of a Septum magnet for ThomX accelerator

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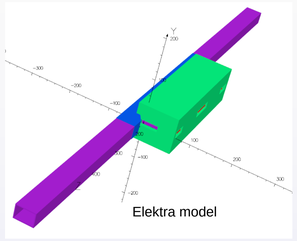
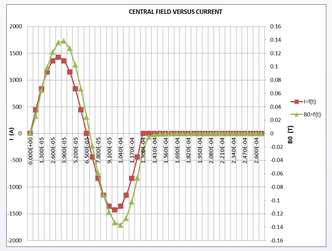
ABSTRACT

ThomX is a Compton source project in the range of the hard X rays (40 / 90 keV). The machine is composed of an injector Linac and a storage ring where an electron bunch collides with a laser pulse accumulated in a Fabry-Perot resonator.
The injection and extraction of the beam in the storage ring is managed by an UHV eddy current septum magnet. This eddy current septum magnet has to generate a full sinus pulse, 150 mT peak and 130µs period. Magnetic and thermal 3D models, have been performed on OPERA FEA Software (ELEKTRA and TEMPO solvers), to analyse the transient behavior of the magnet. Results of this modelling are presented.

3D TRANSIENT – CALCULATION

PARAMETERS	Customer specification	SIGMAPHI specification	SIGMAPHI 3D calculation
resonance frequency	7692Hz	7692Hz	7692Hz
Operating frequency	50Hz	50Hz	50Hz
Gap	12mm	12mm	12mm
Ampere turns per pole	1426A (1 turn)	1426A	1426A
Stored Energy	Not specified	<2J	1.1J
Maximum field - Bmax	149.3mT	138.5mT	138.5mT
Effective length (straight analysis)	250mm	259.45mm	259.45mm
Maximum integrated field – BImax	37.33T.mm	35.94T.mm	35.94T.mm
Good field region dimensions	Horizontal ±17.5mm Vertical ±2.5mm	Horizontal ±17.5mm Vertical ±2.5mm	Horizontal ±17.5mm Vertical ±2.5mm
Transverse Field homogeneity - dB/Bo	Not specified	$\Delta<5x10^{-2}$	$-5x10^{-3}/3x10^{-2}$
Integrated Field homogeneity - dBL/Blo	$\Delta<5x10^{-3}$	$\Delta<1x10^{-1}$	$-8.6x10^{-3}/4.8x10^{-2}$
Beam radius	1570.524mm	1570.524mm	1570.524mm
Beam angle	9.1673°	9.1673°	9.1673°
Beam size	Ø5mm	Ø5mm	Ø5mm
Effective length (curved analysis)	250mm	261.15mm	261.15mm
Transverse Field homogeneity - dB/Bo (curved analysis)	Not specified	$\Delta<1x10^{-3}$	$-1.2x10^{-4}/3x10^{-5}$
Integrated Field homogeneity - dBL/Blo (curved analysis)	$\Delta<5x10^{-3}$	$\Delta<1x10^{-3}$	$-1.91x10^{-4}/1.19x10^{-4}$
Leakage field integral	3.73x10^{-4}T.mm	<3.73x10^{-4}T.mm for Z from -210mm to 210mm	4.4x10^{-3}T.mm Z from -1000mm to 1000mm 1.36x10^{-4}T.mm Z from -210mm to 210mm





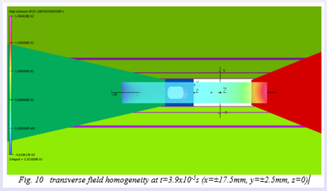


Fig. 10 transverse field homogeneity at t=3.9x10^{-2}s (x=±17.5mm, y=±2.5mm, z=0)

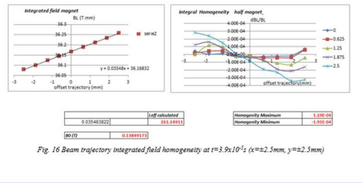


Fig. 16 Beam trajectory integrated field homogeneity at t=3.9x10^{-2}s (x=±2.5mm, y=±2.5mm)

Laminated yoke
- Thickness: 0,23mm
- Insulation: 10Ohm.cm^3 per face

=> anistotropic electrical conductivity Cz=1 S/mm

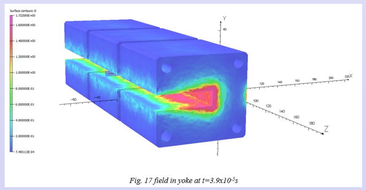


Fig. 17 field in yoke at t=3.9x10^{-2}s

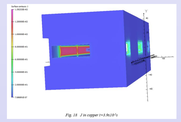


Fig. 18 J in copper t=3.9x10^{-2}s

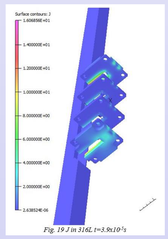


Fig. 19 J in 316L t=3.9x10^{-2}s

Fied values in Tesla
Currents density in A/mm²
Time in second

Leakage field

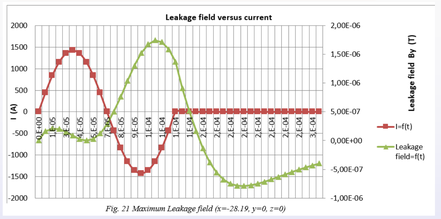
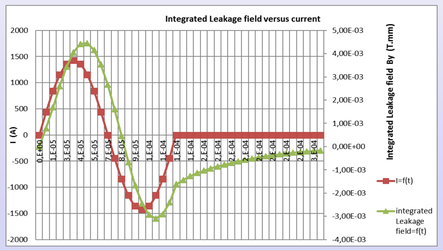
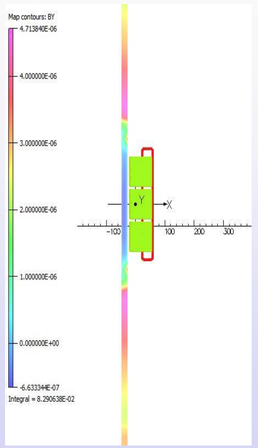
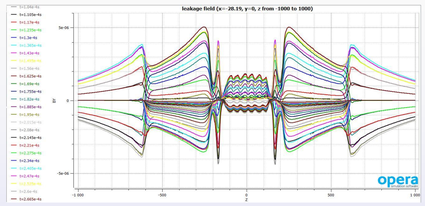


Fig. 21 Maximum Leakage field (x=-28.19, y=0, z=0)

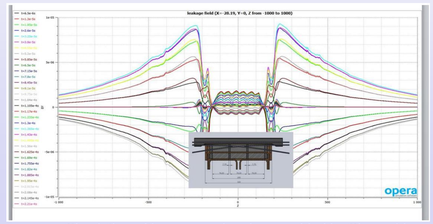




Leakage field (in Tesla)
in circulated beam middle plane area

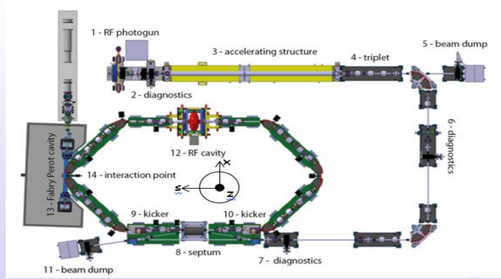


Simulation with extended vacuum chamber

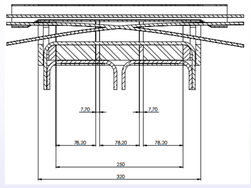


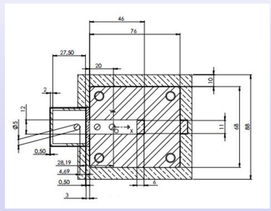
Simulation with vacuum chamber provided by Sigmaphi

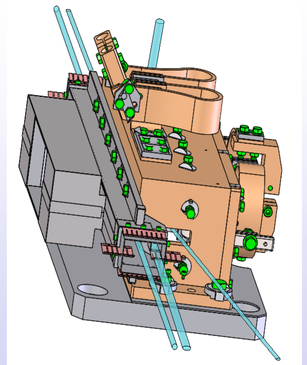
THOMX - Layout

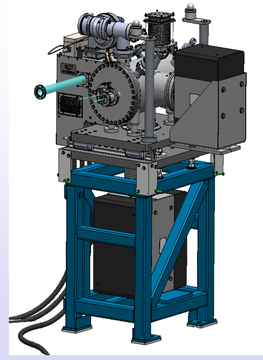


CAO septum magnet





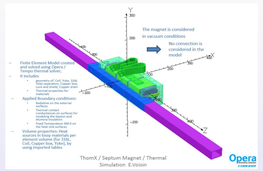


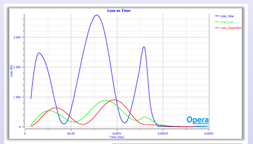


Preliminary design
Use for 3D simulations

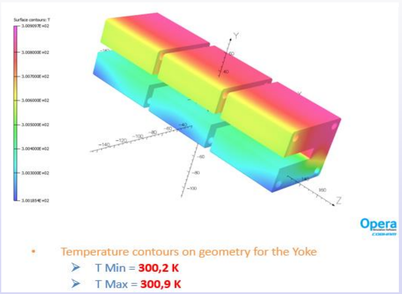
Final design

Thermal Simulation

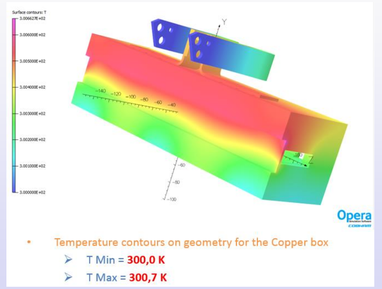




- Mean Loss during the pulse (Integrated Loss / Pulse duration)
  - 316 L : 336 W
  - Copper box : 315 W
  - Iron Yoke : 1241 W
- Mean Loss per cycle (Alpha * Mean Loss pulse)
  - 316 L : **2,2 W**
  - Copper box : **2 W**
  - Iron Yoke : **8,1 W**



- Temperature contours on geometry for the Yoke
  - T Min = **300,2 K**
  - T Max = **300,9 K**



- Temperature contours on geometry for the Copper box
  - T Min = **300,0 K**
  - T Max = **300,7 K**

CONCLUSIONS

3D transient simulations allowed us to evaluate field attenuation and delay. It also give us a better knowledge of the integrated leakage field distribution in an eddy current septum magnet (importance of leakage field after septum blade, impact of vacuum chamber on leakage field reduction), it will help us during magnet measurements that will be done in the coming months.