ThomX: Beam Diagnostics

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ThomX

Figure: ThomX localisation : inside the Iglex

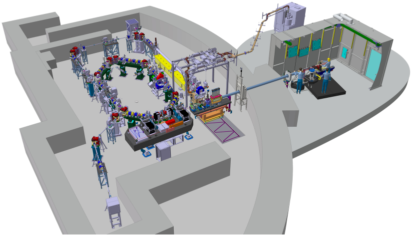


Figure: ThomX overview

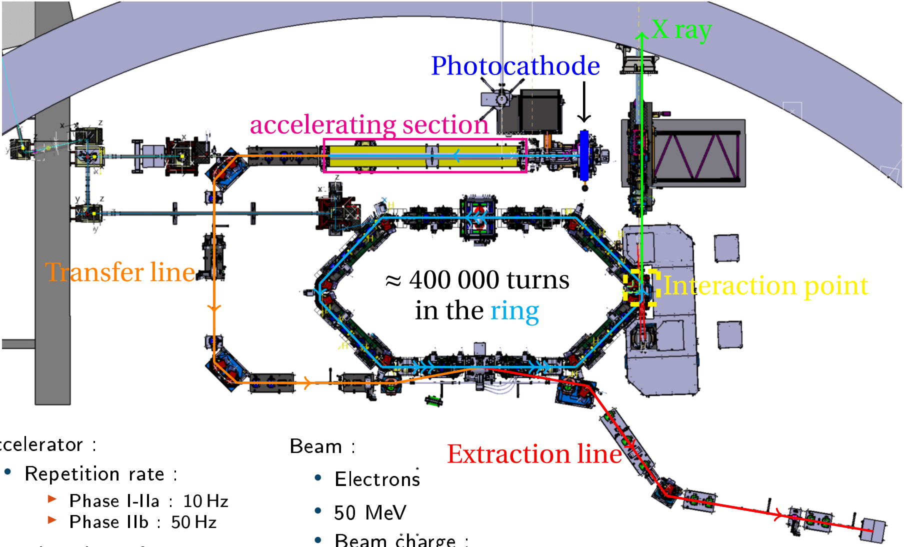
- ThomX goal :
  - High x-ray flux
  - Compact machine
- Principle :
  - Compton backscattering : Diffusion of photon onto energetic electron
- History :

2009	First discussion
2012	Funding : Equipex ANR-10-EQPX-0051
2016	Works start inside the Iglex
Mai 2021	ASN authorisation for phase Ia
June-Sep.	RF gun and LIL section commissioning
4-10-2021	First electron beam
Nov. 2021	Phase 1 nominal parameters : 50 MeV; 0.1 nC; 10 Hz
Now	Beam characterisation and machine alignment

- Next steeps : Need ASN authorisation

Phase 2	TL, EL and ring commissioning First x-rays
Phase 2bis	50 MeV; 1 nC; 50 Hz

ThomX seen from above



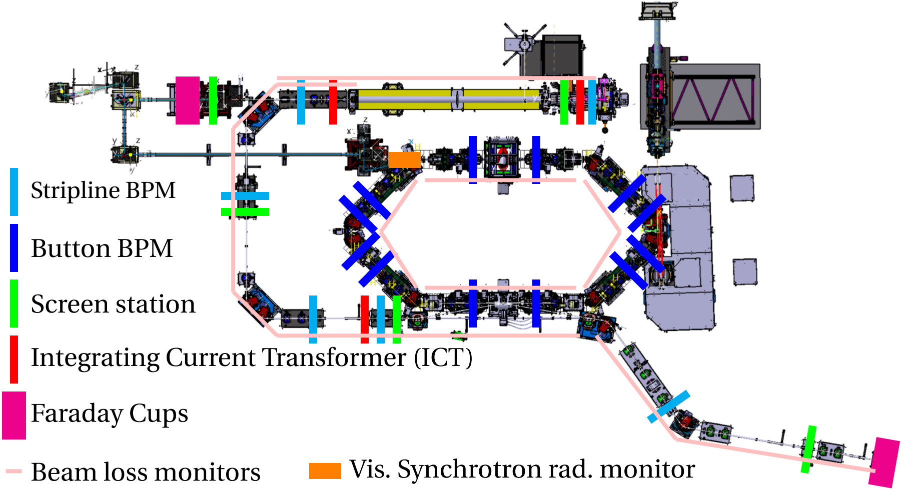
Accelerator :

- Repetition rate :
  - Phase I-IIa : 10 Hz
  - Phase IIb : 50 Hz
- Ring circumference : 18 m
- Fast injection kicker : 50 ns

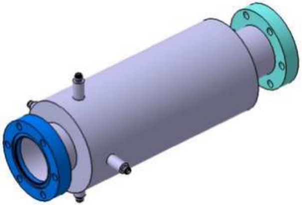
Beam :

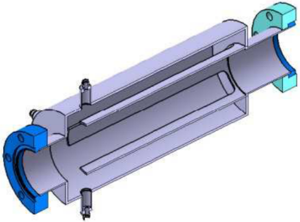
- Electrons
- 50 MeV
- Beam charge :
  - Phase I-IIa : 0.1 nC
  - Phase IIb : 1 nC

Diagnostics



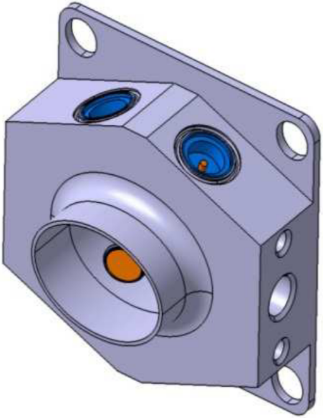
Beam Position Monitor (BPM) : Stripline

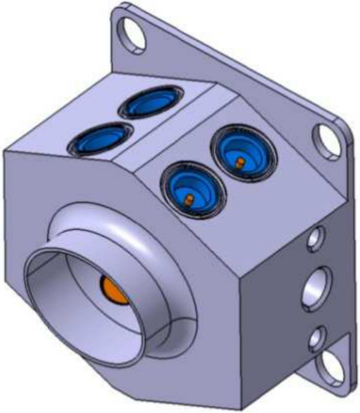




- Linac :
  - # BPM : 1
  - Electrode length : 100 mm
- LT, EL
  - # BPM : 5
  - Electrode length : 150 mm ($= \lambda/4$ at 500 MHz)
- Required resolution : 100 µm
- Work mode : single pass (50 Hz)

Beam Position Monitor (BPM) : Button





- Ring
- # BPM : 12 (4 with 2 quadruplet of electrodes to clean ions)
- Electrode length : 10.7 mm
- Required resolution : 1 µm at 50 Hz
- Work mode : Turn-by-turn (18.7 MHz)

Electronics : Libera Brillance+

Figure: Chassis Libera Brillance+. 4 BPM per chassis.

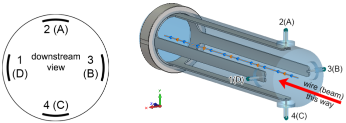


Figure: BPM in transverse plan.

Similar electronics as the one used at SOLEIL.

$$X = K_X \frac{V_a - V_c}{V_a + V_c} + X_{offset}$$

$$Y = K_y \frac{V_b - V_d}{V_b + V_d} + Y_{offset}$$

K_i : Conversion factor to nm
V_i : Current on electrodes i
Offset defined using a Vector Network Analyser (VNA).

5 chassis Libera :

- 3 for the ring
- 1 for the TL
- 1 for the linac and the EL

Libera : acquisition system

- **TBT** : Turn by Turn
- **TDP** : Time Domain Processing
- **DDC** : Digital Down Conversion

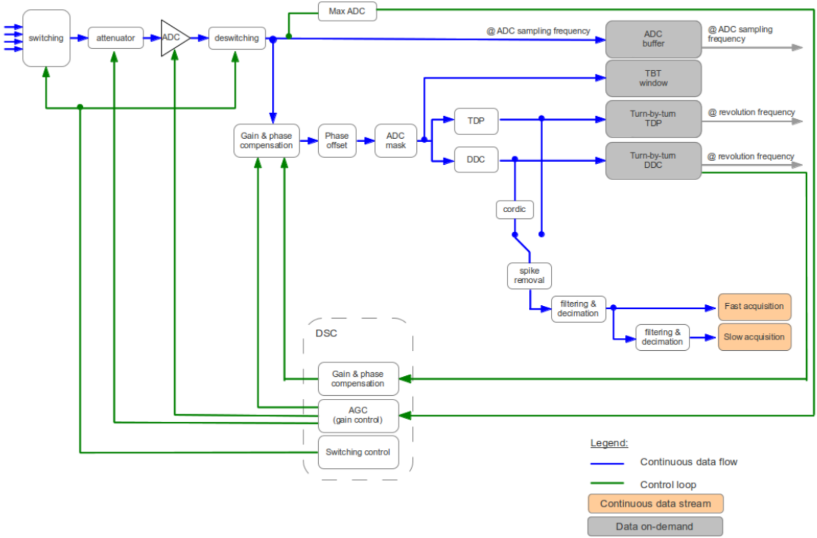


Figure: Schematic of acquisition system of Libera Brillance+ (User manuel Libera Brillance+, version 2.81)

Mode "single pass"

ADC graphique

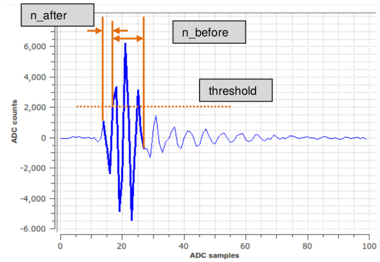


Figure 24: Single pass parameters

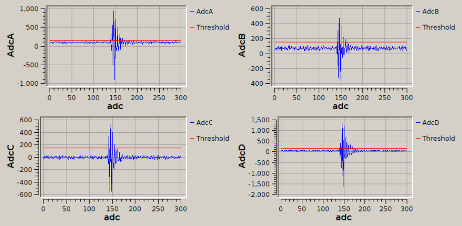


Figure: Visualisation of ADC count on each electrodes of the first BPM of the TL. Beam charge : 30 pC.

V_i = Quadratic mean of the highlighted signal

Button BPM : Mode Turn-by-turn
⇒ see presentation "RIF visio 15 : Présentation des BPM de ThomX" (9 Nov. 2020)

Offsets measurements : Lambertson method

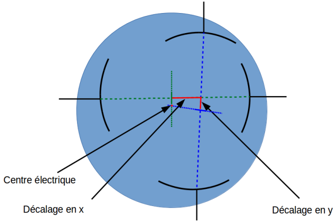


Figure: Sketch of electrical "offset" in a BPM

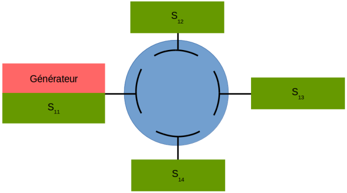


Figure: Sketch of electrical "offset" measurement

$$offset_x = k_x \times \frac{\sqrt{10^{S_{x,ijk}/20}} - \sqrt{10^{S_{x,npq}/20}}}{\sqrt{10^{S_{x,ijk}/20}} + \sqrt{10^{S_{x,npq}/20}}} \quad (1)$$

With :

$$S_{x,ijk} = S_{32} + S_{42} - S_{43} \qquad et \qquad S_{x,npq} = S_{14} + S_{42} - S_{21} \quad (2)$$

Measurement done using a Vector Network Analyser (VNA)

Screen station

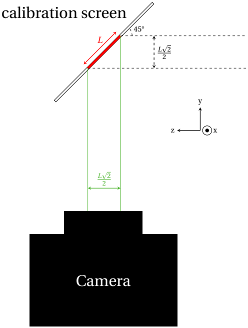


Figure: Calibration screen

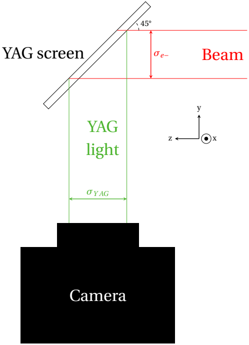


Figure: YAG screen

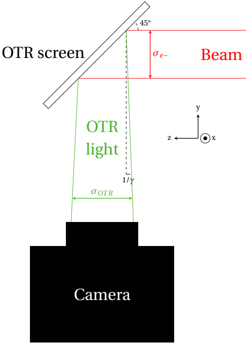
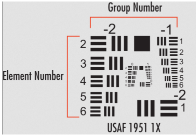


Figure: OTR screen

Resolution (line paire/mm) :

$R = 2^{\text{group}+(\text{element}-1)/6}$



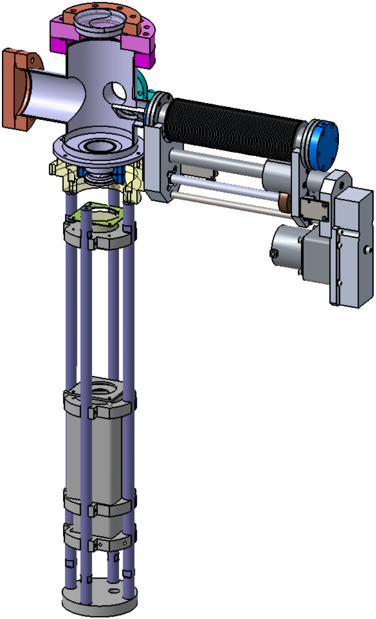
Emitted light :

$N_{YAG} = 13 \times 10^3\ \text{ph/e}^- \times N_{e^-}$

Emitted light :

$N_{OTR} = 1 \times 10^{-2}\ \text{ph/e}^- \times N_{e^-}$

Screen station



Optical lens :

- Actual lens
  - Tamron : 18-400mm F/3.5-6.3 Di II VC HLD
  - Focal length : 18-400mm
  - f-number : F/3.5-6.3
  - diameter : 79 mm
- Old lens
  - 75mm MegaPixel fixed focal length lens
  - Focal length : 75mm
  - f-number : F/2.8-16
  - diameter : 35 mm

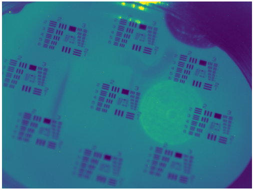
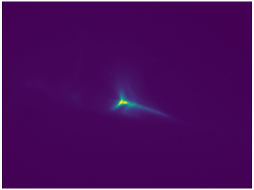
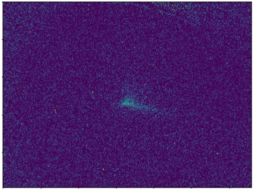
Camera :

- Basler Scout
  - Basler Scout sc640-70gm : CCD sensor
  - Pixel size : 7.4 µm×7.4 µm
  - # of pixel : 659 px × 494 px
- Basler ACE
  - Basler ACE acA3088-16gm : CMOS sensor
  - Pixel size : 2.4 µm×2.4 µm
  - # of pixel : 3088 px × 2064 px

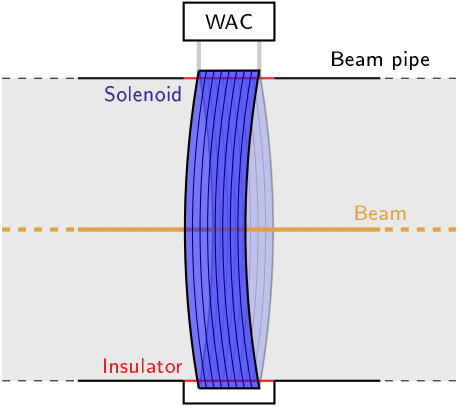
Motor :

- Steep motor : McLennan 23HT18C
- Controlled by an IcePapController

Screen station

Calibration target.	YAG light. (30 pC; 1 ms)	ORT light. Subtraction of 2 images : one with beam, one without. (30 pC; 10 s; 10 Hz)
		
At 100 pC :	$N_{YAG} \approx 5 \times 10^{12}$ ph	$N_{OTR} \approx 10^8$ ph
Emission angle :	4π rad	Cone $1/\gamma \approx 10$ mrad
Detection efficacity :	3×10^{10} ph	2×10^6 ph
Photon/pixel : (1 mm spot; 100 pC)	4×10^6	1.4×10^3
Emission range :	500-700 nm	30 % over 700 nm
High-pass filter at 700 nm : (1 mm spot; 100 pC)	6.9×10^3 ph/px	4.3×10^2 ph/px

Charge measurement : ICT



ICT :

- 3 ICT
- Model : ICT-CF6”—60,4-UHV-070-5.0
- Standard response :
  1 nC ⇒ 5 nVs ie 100 pC on 50 Ω

Acquisition system :

- Wavecatcher (WAC)
- 12 bit ADC @ 3.2 GHz

Charge measurement : FC

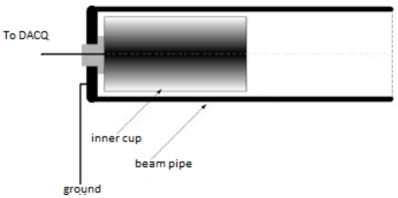


Figure: Faraday cup

Faraday Cup :

- 2 FC
- Used as beam dump
- Current : $I_{pk} = \frac{Q}{\sigma\sqrt{2\pi}}$

$\Rightarrow$ $I_{pk} = 100\,\text{A}$ for $\sigma = 4\,\text{ps}$ at $1\,\text{nC}$

$\Rightarrow$ $5\,\text{kV}$ at $50\,\Omega$
Signal need to be integrating.

Integration system :

- Long cable :
  - 30 m long cable
  - Low-Loss Coaxial Cables : LMR 200
- 10 MHz band pass filter at the end of the cable

Acquisition system :

- Same Wavecatcher as ICT and BLM

Integration system : Test on bench

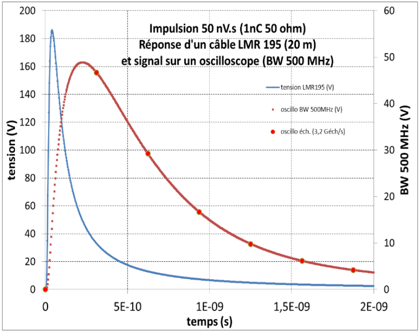


Figure: Integration with cable

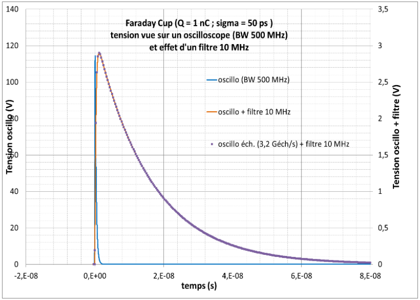


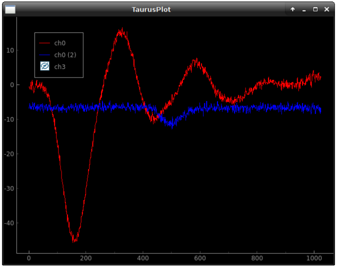
Figure: Integration with band pass filter

Problem :
The output of the FC is not adapted to the 50 Ω $\Rightarrow$ re-bounce.

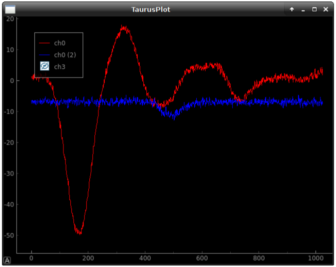
Integration system : Problem of adaptation

Test with other filter and filters configurations : (≈30 pC; 50 MeV)

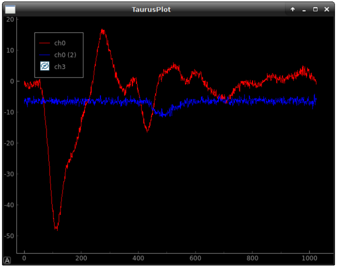
Red : Faraday cup; Blue : ICT



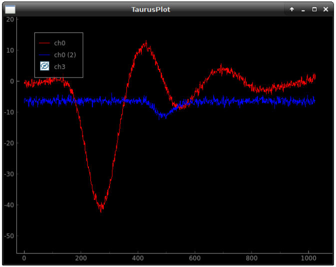
(a) 30 m cable + filter



(b) filter + 30 m cable



(c) Home-made filter + 30 m cable



(d) Home-made filter + 30 m cable + filter

Thanks for your attention !

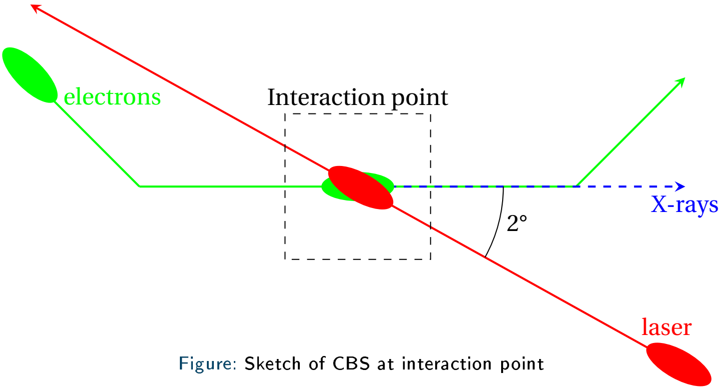


Figure: Sketch of CBS at interaction point

	Electron	Laser	X-ray
Energy	50 MeV	1 eV (1030 nm)	46 keV
Transverse beam size (RMS)	70 µm	70 µm	10 cm in exp room
Longitudinal beam length (RMS)	5 →20 ps × c	10 –20 ps × c	Beams overlap
Repetition rate	17.8 MHz	35.6 MHz	17.8 MHz

$E_{CBSmax} = 4\gamma^2 \times E_{laser}$ ⇒ Adaptation of x-ray energy

Backup

X-rays

Specification :

- Hard X-ray : ≈ 50 keV (90 keV with 70 MeV electrons)
- Adjustable energy
- Monochromatic by collimation
- Flux : 10^{11} - 10^{13} photon/s
- Beam size : 10 cm

Application :

- Radiography
  - Study of artwork
  - Medical radiography (lungs radiography)
- Radiotherapy
  - Therapy by irradiation
  - Use monochromatic x-ray to excite specific target within tumour to "burn" them
- Absorption Tomography
- Crystallography
- Protein structure determination
- Protein dynamic studies

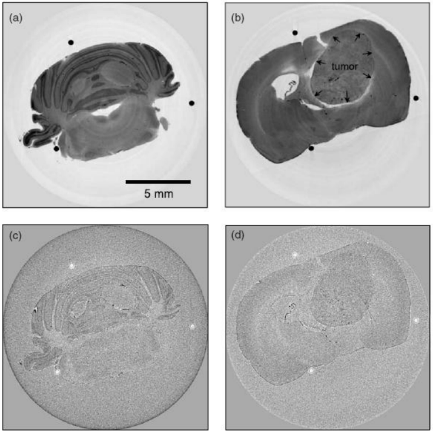


Figure 4 : Phase and attenuation-based tomography results. (a) Phase tomography slice through the rat's cerebellum showing a clear contrast between the white and gray brain matter. (b) Slice through a region of the brain containing a tumor (arrows indicate the tumor's 'pushing front', the border between the tumor-invaded and healthy brain tissue). (c) and (d) Corresponding slices through the absorption-based reconstruction of the specimen. All images are displayed on a linear gray scale corresponding to $\pm 2\sigma$, where σ is the standard deviation of the pixel gray values in the image.

Backup

Injection process

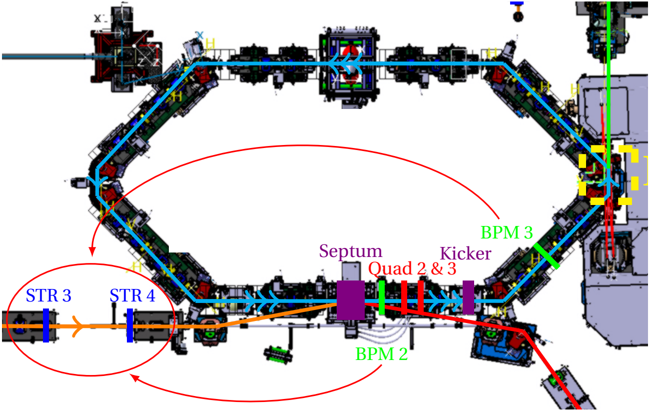


Figure: ThomX overview with principal component

To improve the injection :

- Measure the beam position in the first 2 Beam Position Monitors (BPM) of the ring (RI-C1/DG/BPM.02 and RI-C1/DG/BPM.03).
- Use this measure to calculate the correction that needs to be applied to the last 2 magnetic steerers of the transfer line (TL/AE/STR.03 and TL/AE/STR.04). The kicker strength is also modified to smooth the injection.