Updates for the GammaFactory POP IP

2019 01 29

LAL group

Laser parameters

- From simulations, the preliminary laser parameters are:

Parameters	Values	Unit	Comment
central wavelength	1030-1040	nm	On wavelength fixed in this range
Central wavelength tunability	0.2	nm	
spectral bandwidth [a]	0.1-0.5	nm	TBP limited pulse, chirped pulse ?
Pulse length	3-15	ps	Spectrum shap dependent, Gaussian assumption
Frep [b]	40	MHz	
Phase jitter	<10	fs	10Hz-10MHz, strongly limit possible supplier
average Power	40	W	vary vs the spectral setting / vs TBC
Energy/pulse	1	uJ	vary vs the spectral setting
polarisation	circular	-	
beam diameter	1 - 2	mm	Ajustment with telescope for coupling optimization to OC
beam quality, M^2	<1.2	-	

[a] possibly tunable but easier operation at fix value. Spectral shaping with sharp edge in the blue

[b] with a coarse (+/- 15kHz) and fine tuning with a piezo stack

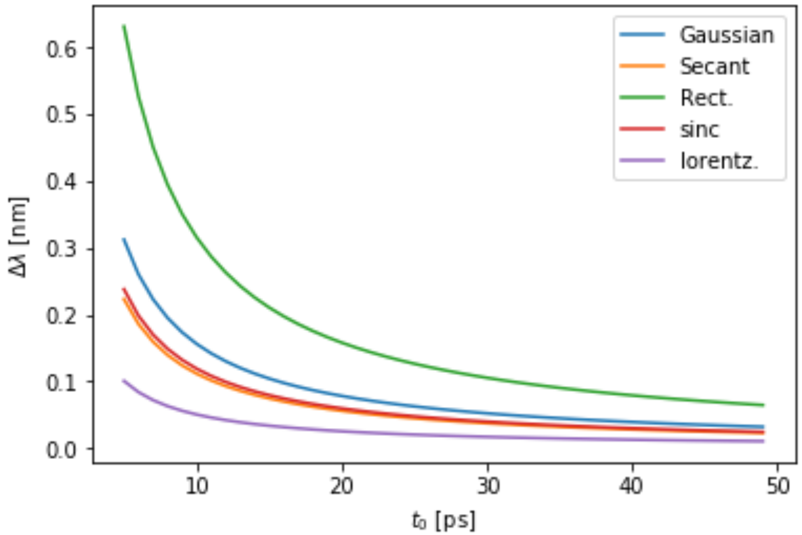
- Feasible custom commercial laser.

Time bandwidth product, FTL pulse versus chirped pulse

- For a Fourier transformed limited pulse

$$\Delta\nu \cdot \Delta\tau = \frac{c\Delta\lambda}{\lambda^2} \cdot \Delta\tau \geq K$$
$$\Delta\tau = t_0$$

Shape	$\varepsilon(t)$	K
Gaussian function	$\exp[-(t/t_0)^2/2]$	0.441
Exponential function	$\exp[-(t/t_0)/2]$	0.140
Hyperbolic secant	$1/\cosh(t/t_0)$	0.315
Rectangle	–	0.892
Cardinal sine	$\sin^2(t/t_0)/(t/t_0)^2$	0.336
Lorentzian function	$[1+(t/t_0)^2]^{-1}$	0.142



$$\varepsilon(z,t) = \int_{-\inf}^{+\inf} \varepsilon(\omega)\exp(-i(\omega t - \phi(\omega))\,d\omega$$

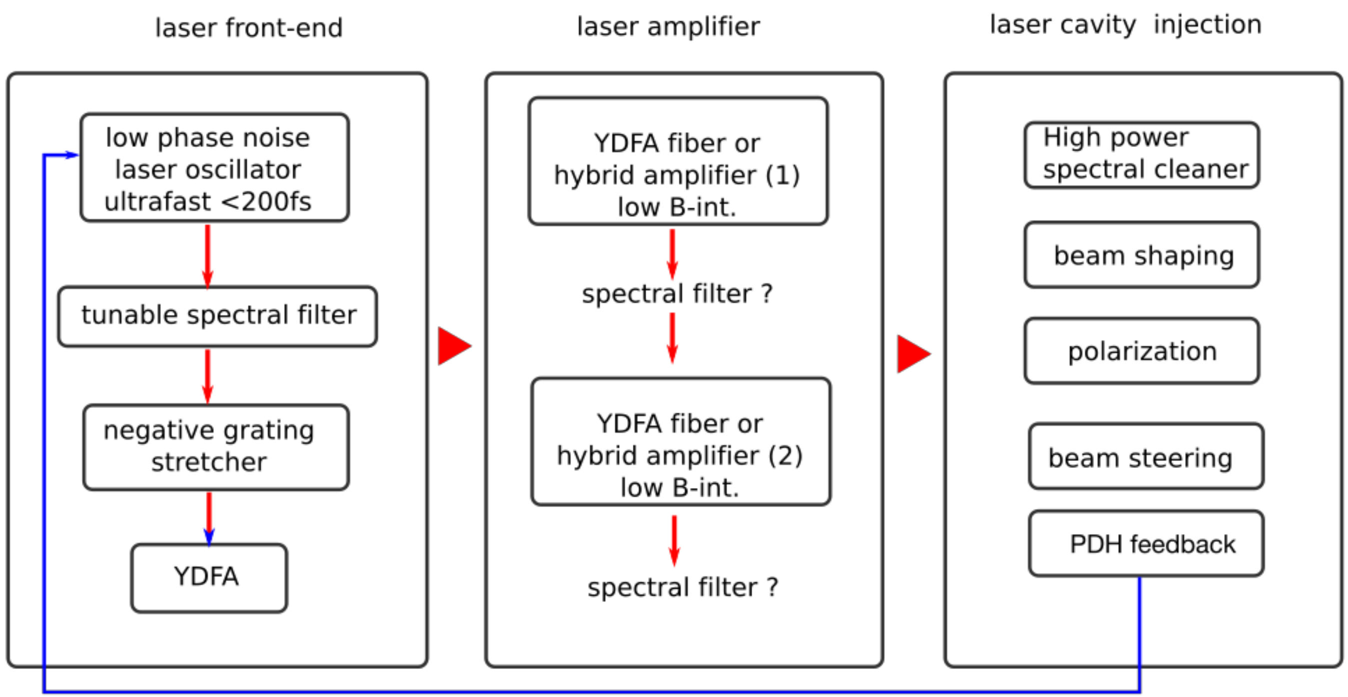
$$\phi(\omega) = k(\omega)z = \sum_{0}^{\inf} \frac{\omega - \omega_0^m}{m!}\frac{\partial^m}{\partial\omega^m}|_{\omega=\omega_0}$$

m=2, quadratic phase => linear chirp

- If group delay dispersion has marginal effect on ion beam cooling, pulse length t_0 and spectral bandwidth can be decoupled by non-compensating the dispersion or adding dispersion

Progress in laser design considerations

Not a lot of progress, sourcing to identify supplier and laser design under discussion



New Optical cavity proposal

AM shows that a most simpler design with 2 mirrors (plan-concave) cavity is giving us :

Parameters	Values 2-mirrors OC	Values 4 mirrors (3D-OC)	Unit	Comment
Crossing angle	2.4	2.6	°	
waist_x @ IP	~1.4	~1.9	mm	
waist_y @ IP	~1.4	~1.7	mm	
Minimum waist	1.25		mm	On the coupling mirror
Max length	3,75	3,25	mm	
Beam diameter M1	1.25	2	mm	
Coupling	~ 70	~70	%	
Gain	>5000	>5000		Limited by oscillator phase noise
Stored power	>100	>100	kW	

The 2 mirrors OC has many advantages:

- easier alignment can be made without breaking vacuum
- minimized optomechanics under vacuum
- may be some pros for beam impedance issue

Rough integration design approach

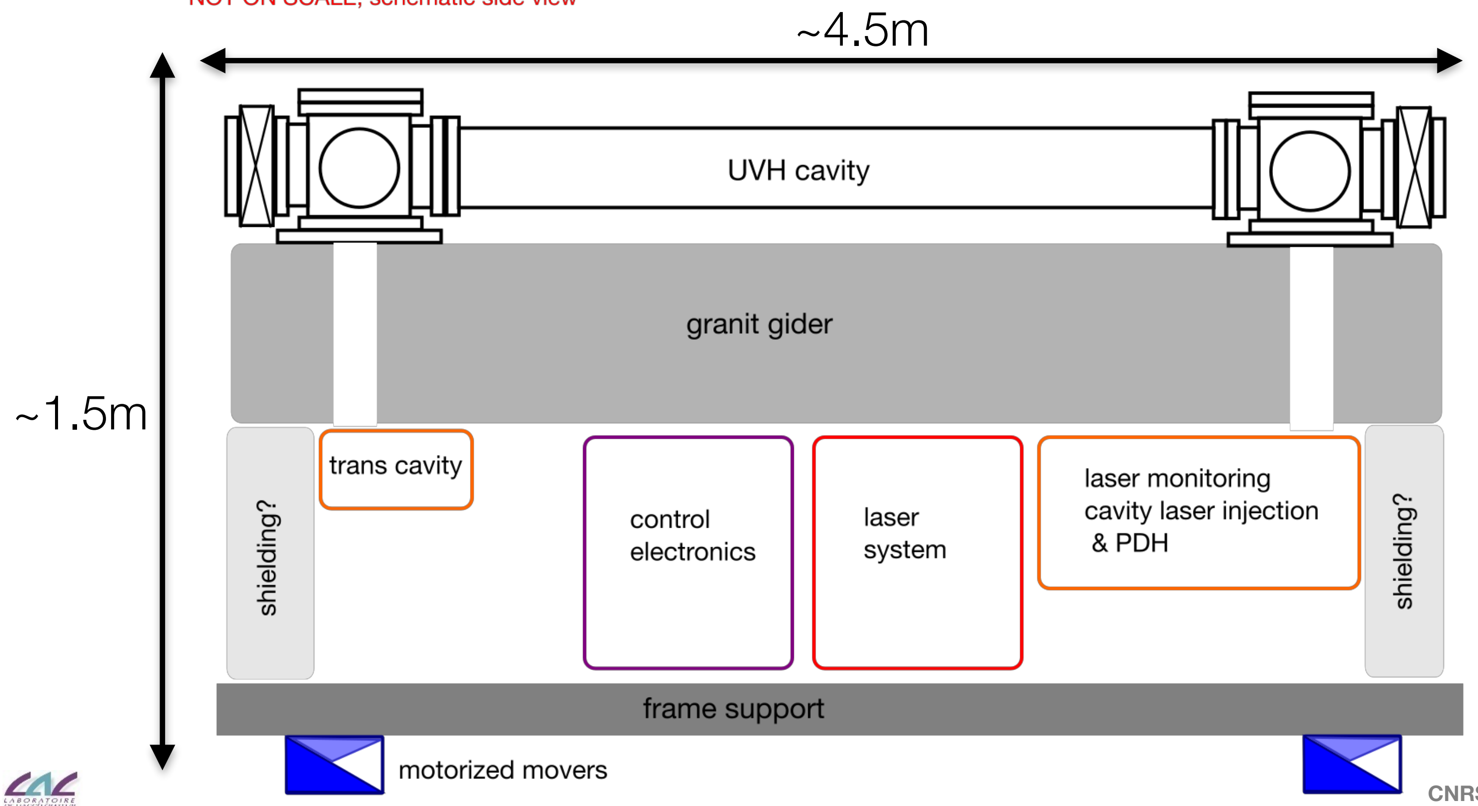
First schematic of the interaction point system design guidelines integration :

- comes as a module in SPS, except possible chiller for the laser amplifier, power supply ?

Volume ~ 10 m^3

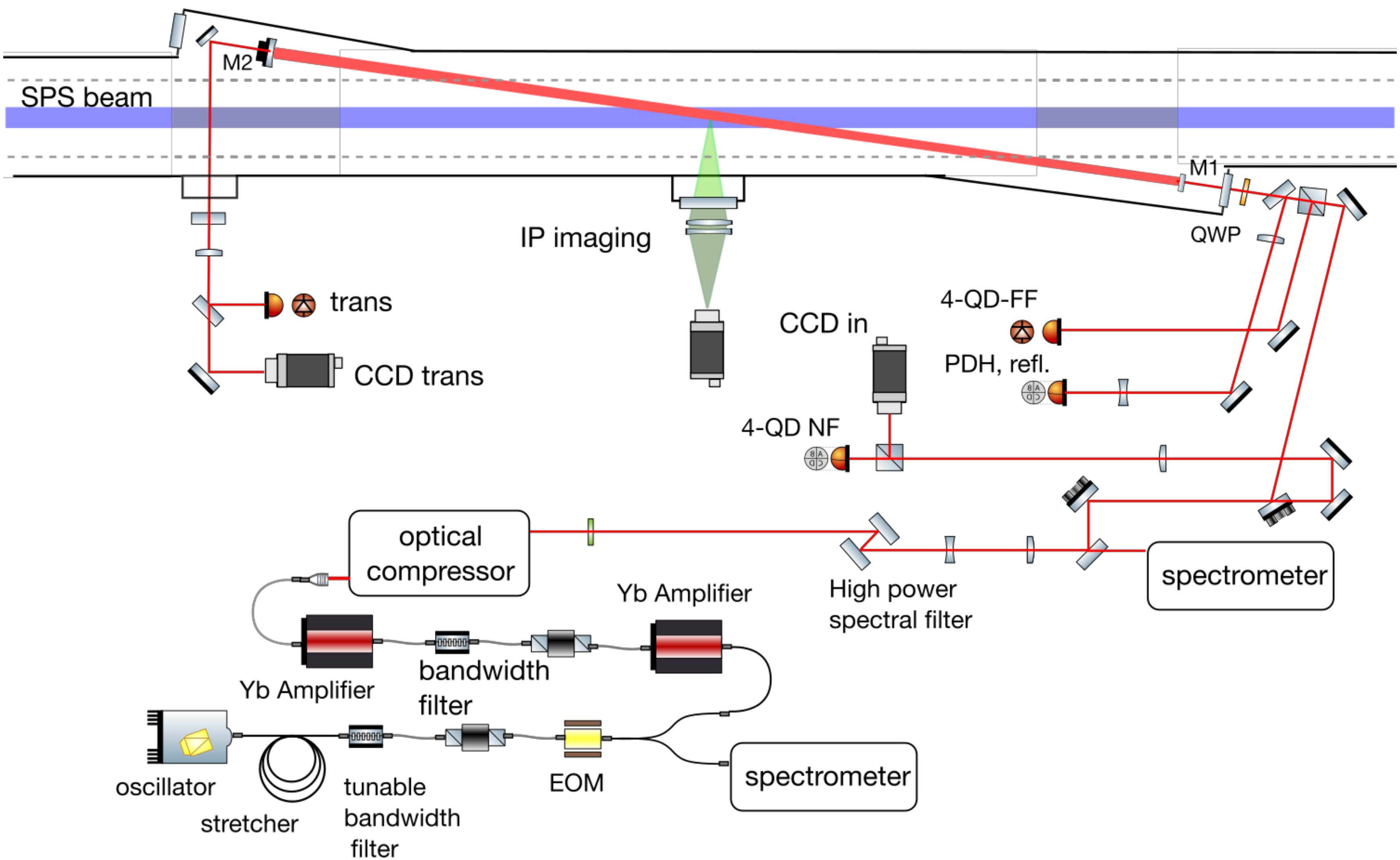
- rack unit for laser and electronic easy to plug or un plug.
- epoxy granit ? Or honeycomb optical table, environment T°C variation and radiation must be adresse

NOT ON SCALE, schematic side view



Optical scheme interaction point system

Not on scale unfolded view



Radiation hardness issue

Long Straight Section	Position	Height	SEU 3V	SEU 5V	R-factor	Φ_{HEH} [pp/cm²]	Φ_{ThN} [pp/cm²]
LSS4	A	Beam	20963	10498	0.1	8.88×10^9	8.30×10^8
	B	Floor	10351	1177	1.9	8.80×10^8	1.64×10^9
LSS6	E	Beam	N/A	17577	0.1*	1.50×10^{10}	1.40×10^9
	F	Floor	20181	N/A	1.9*	2.04×10^9	3.81×10^9

Long Straight Section	Position	Height	TID [Gy]
LSS4	A	Beam	10.5
	B	Floor	4.8
LSS4	C	Beam	5.4
	D	Floor	3.9
LSS6	E	Beam	9.8
	F	Floor	4.0

- How it scales after one year in SPS?
- Results in favor of LSS4 ?
- SEU seems large special power supply and electronics required ?
- What about shielding ?

Bibliography comparison

G. Buchs *et al* . « Radiation hard mode-locked laser suitable as a spaceborne frequency comb » OPTICS EXPRESS Vol. 23, No. 8 (2015)
DOI:10.1364/OE.23.009890

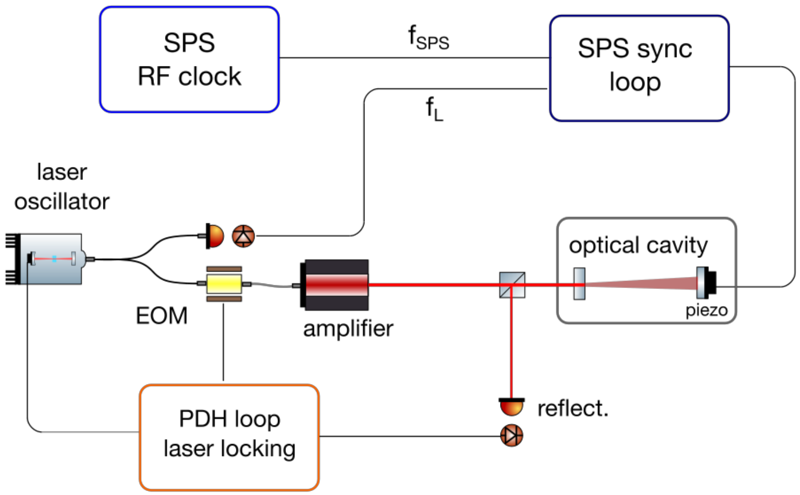
Table 4. Proton fluences applied at each irradiated zone of the laser

Energy (MeV)	First cycle (2.5 years equiv.) protons/cm²	Second cycle (5 years equiv.) protons/cm²
99.7	$3.71 \cdot 10^9$	$7.42 \cdot 10^9$
61.6	$3.61 \cdot 10^9$	$7.22 \cdot 10^9$
30.7	$9.82 \cdot 10^9$	$1.964 \cdot 10^{10}$
18.3	$1.54 \cdot 10^{10}$	$3.08 \cdot 10^{10}$

Required input from CERN SPS

To progress on the general design of the interaction point system :

1. Better understanding of the radiation measurement : shielding design ?
2. RF SPS reference for locking : RF signal to lock the cavity on SPS / how RF is modified



3. Environment condition : temperature variation?
4. Integration constraints and safety : max volume and weight for the IP system, alignment network
5. Control-command and cabling

Next step for LAL team

> **Yellow Report !!**

> Include chirp in software to describe laser pulse - ion bunch interaction.

> Optical cavity design refinement with investigation of thermal effect on the coupling mirror for the 2 mirrors OC

> First proposal of a complete laser architecture and associated budget based on NKT photonics/teraxion proposal

> Investigation of alternative design with NKT oscillator / teraxion (stretcher-spectral bandwidth filter) /Amplitude Amplifier

> Design and test of the high energy spectral shaper (Institut Fresnel)

> Visit SPS and freeze integration interfaces

> Request for LAL design office time to produce first 3D model of the interaction point system