3rd SPARC_LAB PAB Meeting

15:00 Welcome – Umberto Dosselli
15:05 Introduction – Patric Muggli

15:10 SPARC_LAB short term plan – M. Ferrario

15:40 Progress in the installation of the Compton– C. Vaccarezza

15:55 2-color FEL experiment – F. Villa

16:10 Lidar – M. Petrarca

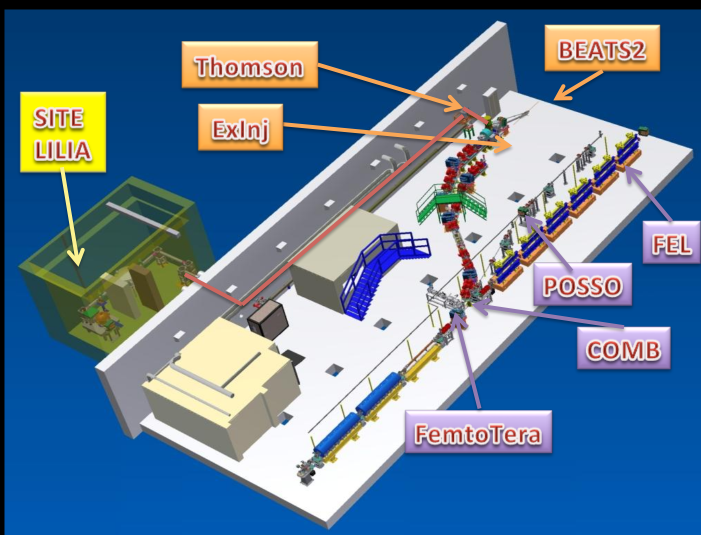
16:25 Results of the electro-optical Sampling for COMB – R. Pompili

16:40 Recent results about proton acceleration (0:15) – D. Giove

00:00 ELI_NP – L. Serafini

16:55 Final discussion – Patric Muggli

3rd SPARC_LAB PAB Meeting



LNF- May 8, 2013

What has been done since PAC2

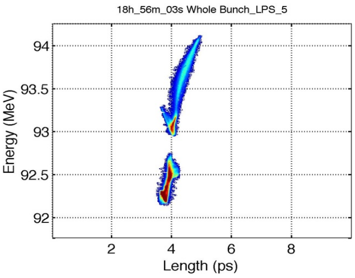
	Nov	Dec	Jan	Feb	March	April
Thomson	Comp. Delivery	Comp. Delivery	Inst.	Inst.	Inst.	Inst.
FEL	Two Colors			Prep. Seeded 2 Colors	Prep. Seeded 2 Colors	Prep. Seeded 2 Colors
THZ	Prep.			Prep.	Prep.	Test
C-band	Inst.	Inst.	Inst.	Inst.	Inst	Inst
Protons	Test	Exp.				
LIDAR				Test	Exp.	
COMB						EOS

TWO COLORS FEL

More details in F. Villa talk

EVIDENCE OF 2-COLORS FEL EMISSION

phS1=298 (88.6 deg off crest)



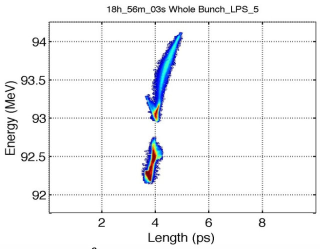
Main parameters	
MeanEnergy(MeV)	93.028 (0.101)
DE(MeV)	0.585 (0.00667)
EnergySeparation (MeV)	1.0735
UncEnergySeparation (MeV)	0.047
TimeSeparation (ps)	0.42
UncTimeSeparation (ps)	0.029
FirstBunchCharge (%)	51.35
SecondBunchCharge (%)	48.65

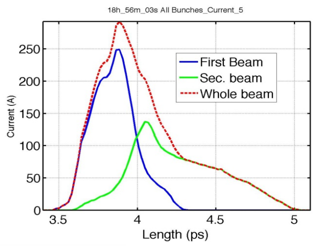
	Energy (MeV)	En. Spread (keV)	En. Spread (%)	Length* (ps)	Charge (pC)
First Beam	92.515(0.033)	160.6(4.5)	0.174(0.005)	0.115(0.002)	82.15(1.58)
Second Beam	93.588(0.033)	296.6(4.9)	0.317(0.005)	0.27(0.003)	77.85(1.56)
Whole Beam	93.038(0.032)	587.3(2.5)	0.631(0.003)	0.29(0.004)	160.00(3.10)

**** Spot RFD off included***

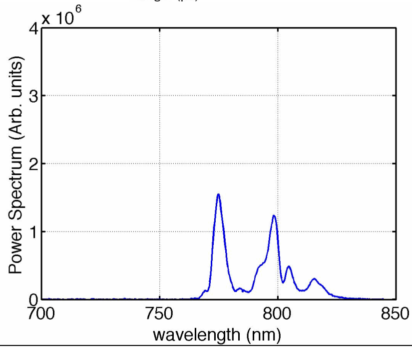
EVIDENCE OF 2-COLORS FEL EMISSION

Spectrometer analysis





The first electron beam is the one with lower energy and higher current: it is responsible of the slight asymmetry in the FEL emission spectra. Indeed, the peak at longer wavelength is more intense due to the higher current.



Mean FEL parameters	
λ_{min} (nm)	778.3 (5.7)
$BW_{\lambda min}$ (%)	0.65
λ_{Max} (nm)	804.0 (4.6)
$BW_{\lambda Max}$ (%)	0.88
$\Delta\lambda$ (nm)	25.8 (4.5)
Energy (μJ)	> 37

Corresponding to a mean energy separation of 1.47 (0.26) MeV

From Joulemeter measurement

Draft to be submitted to PRL.

Observation of time-domain modulation of FEL pulses by multi-peaked electron energy spectrum

V. Petrillo[1], M. P. Anania[2], M. Artioli[3], A. Bacci[1], M. Bellaveglia[2], E. Chiadroni[2], A. Cianchi[4], F. Ciocci[3], G. Dattoli[3], D. Di Giovenale[2], G. Di Pirro[2], M. Ferrario[2], G. Gatti[2], L. Giannessi[3], A. Mostacci[5], P. Musumeci[6], A. Petralia[3], R. Pompili[4], M. Quattromini[3], J. V. Rau[7], C. Ronsivalle[3], A. R. Rossi[1], E. Sabia[3], C. Vaccarezza[2], F. Villa[2].

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[7]*ISM-CNR Via del Fosso del Cavaliere, 100 00133 Roma, Italy*

Abstract

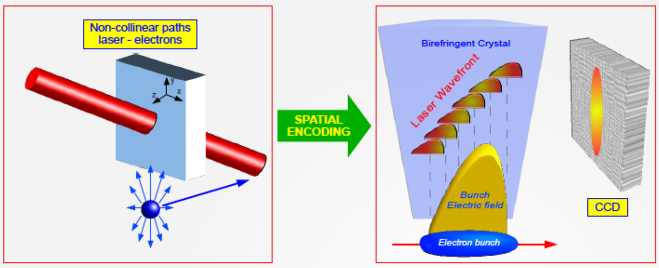
We present the experimental demonstration of a new scheme for the generation of ultrashort pulse trains based on the Free-Electron Laser (FEL) emission from a multi peaked electron energy distribution. Two electron beamlets with energy difference larger than the FEL parameter ρ have been generated by illuminating the cathode with two ps-spaced laser pulses, followed by a rotation of the longitudinal phase space by velocity bunching in the linac. The resulting SASE FEL radiation, measured through a FROG diagnostics, reveals a double-peaked spectrum and a temporally modulated pulse structure.

Next step: Seeded 2 colors FEL

COMB EOS

More details in R. Pompili talk

EOS Spatial Encoding Setup

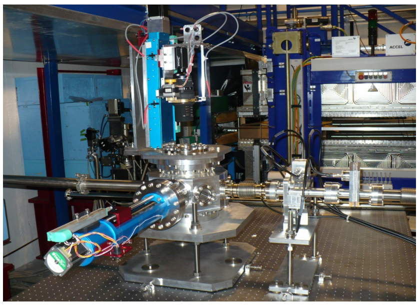


- **Laser crosses the crystal with an incident angle of 30°** → one side of the laser pulse arrives earlier on the EO crystal than the other by a time difference Δt.
- Coulomb field inducing birefringence is encoded in the spatial profile of laser pulse
- Benefits: **simple**, **no high energy laser needed**.
- Drawbacks: **poor surface quality of EO crystals.**

Near Crossed Polarizer Setup

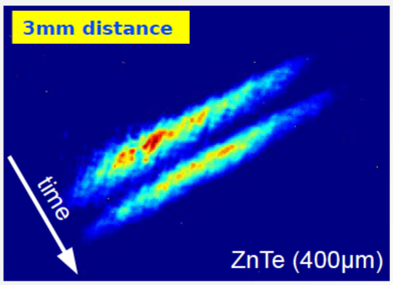
$$I_{det} \sim I_{laser}\, 2\theta\Gamma + 4\theta^2 I_{laser} \sim E_{THz}$$

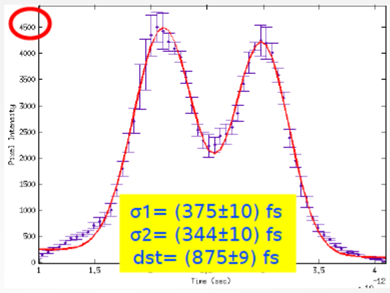
Electro-Optical Sampling



- EOS Chamber realized and installed at the end of SPARC_LAB's 2nd line.
- EOS actuators (target and camera's autofocus [2 axis]) installed and tested.
- EOS Laser Transfer Line realized (12 columns with laser pipe) for IR 800nm.
- Realization of EOS Optics Setup just started.
- YAG and OTR Targets successful tested in EOS Chamber
- First measure of Laser – Electrons Delay realized.

Single shot EOS signals



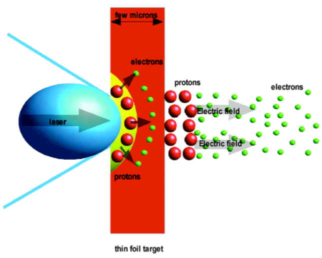


Proton Acceleration

More details in D. Giove talk

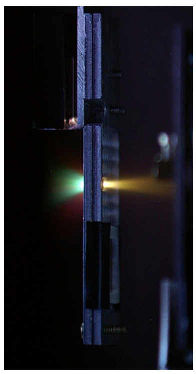
NTA-SL-LILIA (Laser Induced Light Ions Acceleration)

LILIA is an experiment of light ions acceleration trough laser interaction with thin metal targets.
The main goal is to obtain a beam suitable for injection in other accelerating structure.

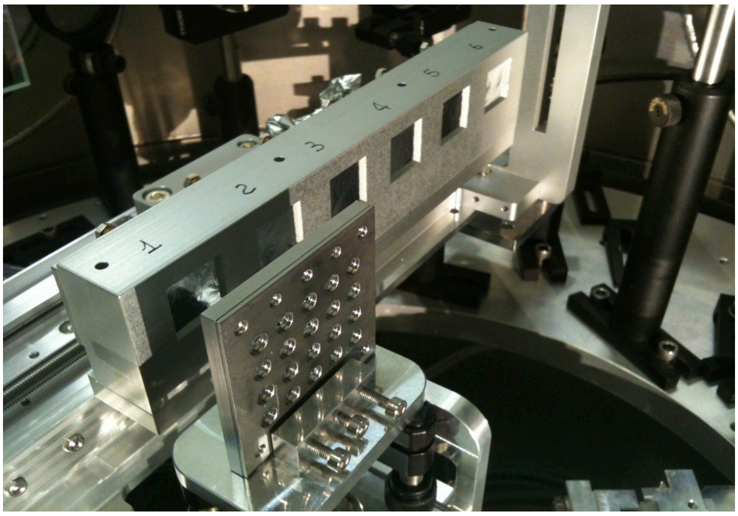


INFN partecipants :

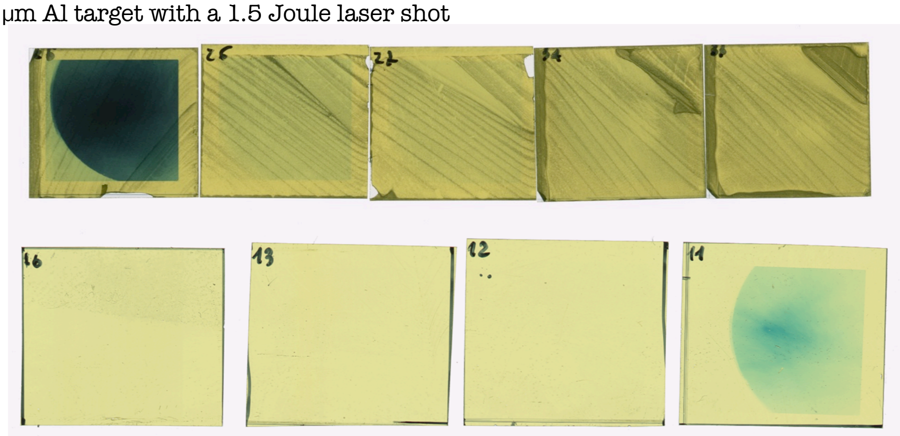
Bologna, Lecce, Milano, Milano-Bicocca, Pisa



Remotely movable radio-chromic detectors and multi-shot target holder installed



First pictures of the EBT3 radio-chromic film impressed by protons emitted from a 3 μm Al target with a 1.5 Joule laser shot



The maximum laser intensity is limited to 10^{19} W/cm^2 due to the lack of a parabola with focal length shorter than the present one. In this configuration, according to performed numerical simulations, we expect a proton beam with maximum energy of few MeV (1.6 MeV) (10 MeV is as of now the maximum energy allowed by the local authorities for the place where the experiment will be located) and total intensities up to 10^{10}-10^{12} protons/shot.

SHORT TERM PROGRAM (till June 2013) : LILIA PHASE I

- A parametric study of the correlation of the maximum accelerated proton energy, with respect to the following parameters:
- Laser pulse intensity (in the range $10^{18} < I < 10^{20}$ W/cm^2)
- Laser pulse energy (in the range 0.1-4 J)
- Laser pulse length (in the range 25 fs-1ps)
- Metallic target thickness (in the range 1-10 microns).
- In such a frame we would like to deeply investigate the experimental scale rules within the possibilities offered by the FLAME facility. Moreover, this will provide the opportunity to get experience in the development of diagnostic techniques and in target optimization.

LIDAR (external user)

More details in M. Petrarca talk

Experiment Proposal:

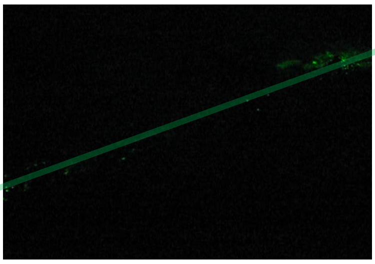
In-situ laser-induced condensation in free atmosphere

Prof J.-P. Wolf group

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

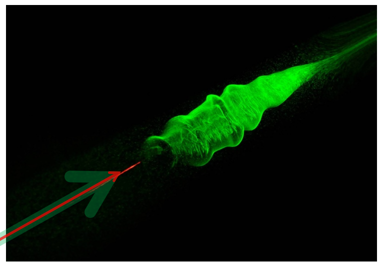
Overview

It has been shown that is possible to trigger the formation of water droplets by intense laser beam in the filamentation regime while propagating in a controlled atmosphere with saturated and unsaturated relative humidity



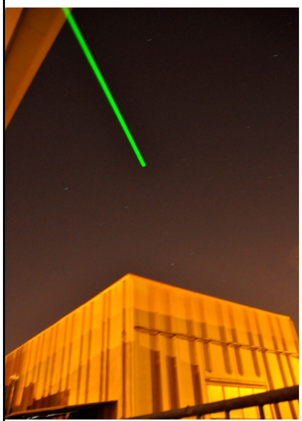
Background: No IR laser, no filament

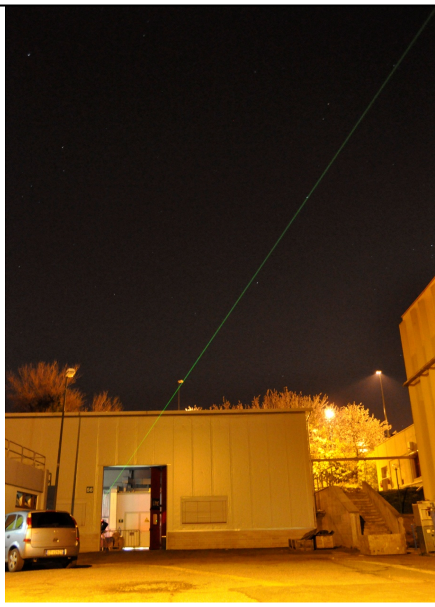
Diagnostic: Green laser scattering from suspended particle



Cloud chamber sub-saturated
RH=(70-90)%
T=20C

P. Rohwetter *et al.*, *Nature Photonics* **4**, 451 (2010)
Y. Petit, Appl. Phys. Letters, **98**, 041105 (2011)
S. Henin et al, Nature Communication, **2**,456, 2011

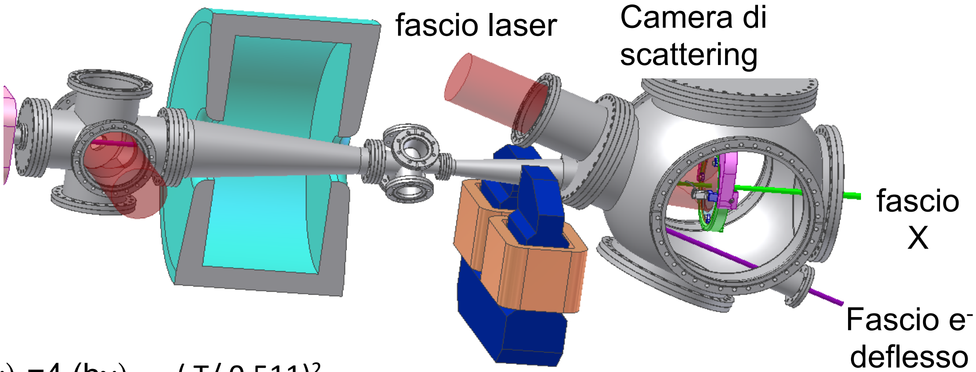




THOMSON

More details in C. Vaccarezza talk

Thomson Interaction region (20-550 keV)

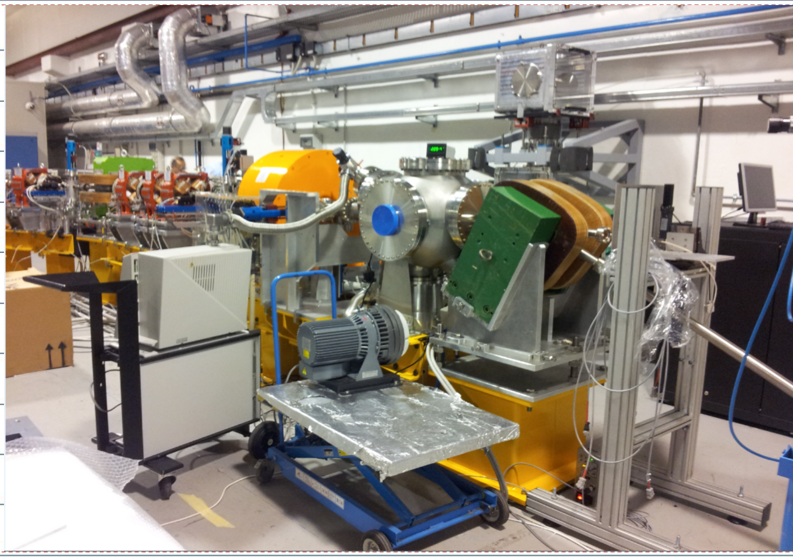


$(h\nu)_X = 4\,(h\nu)_{laser}\,(T/0.511)^2$

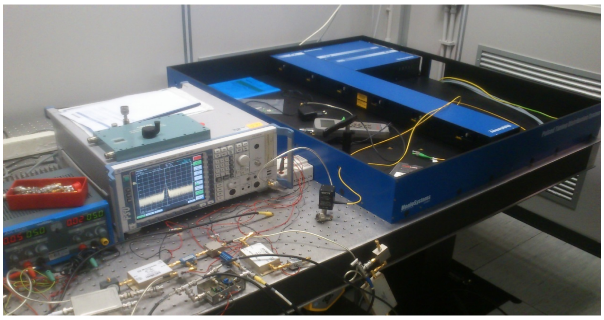
$(h\nu)_{laser}$ = 1.2 eV
T =30.28 MeV
$(h\nu)_X$ = 20 keV mammografia

Impulso laser: 6 ps, 5 J
pacchetto e^- : 1 nC , I: 2 mm (rms)
Impulso X: 10 ps, 10^9 fotoni
α emissione: 12 mrad

One picture



Upgrade to optical synchronization



- The Optical Master Oscillator is installed and working at regime fulfilling the specifications
- Electrical cabling between FLAME and SPARC is established
- FLAME has been locked to the SPARC reference
- The phase resolution of the FLAME locking system must be upgraded
- The fiber connection to distribute the optical reference signal between FLAME and SPARC is under way (cables are installed, but not tested yet)
- Optical synchronization devices are in house, but to be installed

Commissioning:

- 90 MeV – 160 pC e^- beam (Comb or THz exp)
  - Down to dump w flags
  - Quads alignement check on this orbit
  - ➡BPM first reference orbit
  - Response matrix iterations for lattice optimization
- 30 MeV low charge transport and optimization

= 1÷1.5 month (May)

- Photon beam transport & optimization
- Synchronization & Collision

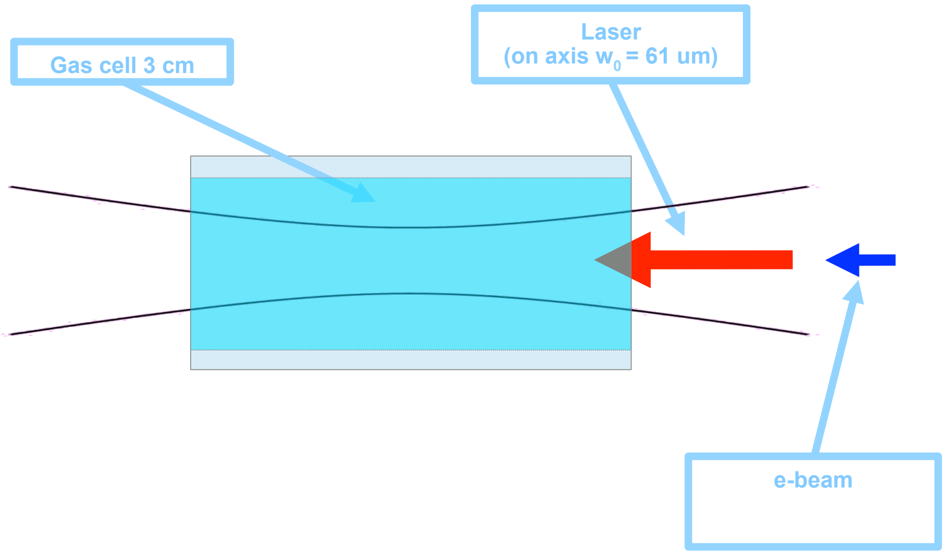
= 1 month (June)

- Al-window
  - Kapton window
    - Carbon fiber window

ExInj-LWFA

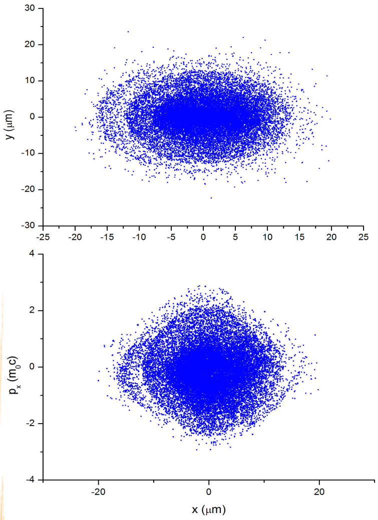
S2E simulation: plasma acceleration

No laser guiding: gas cell, very easy from the experimental point of view.



S2E simulation: plasma acceleration

Sample beam with gas cell (VERY PRELIMINARY): Δt = 157 fs, σ_x = 3.8 μm.



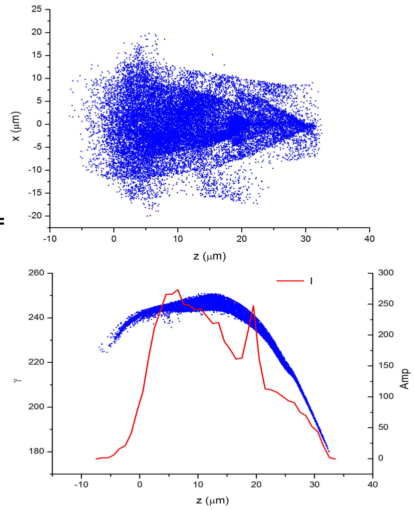
σ_x = 5.4 μm

E = 120 MeV

Charge loss = 8%

ε_{nx} = 4.5 μm

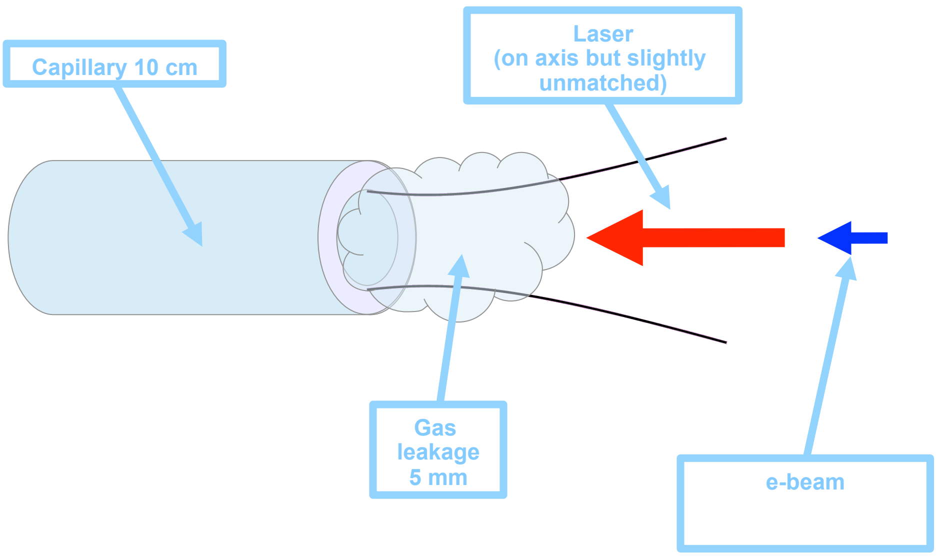
$\Delta\gamma/\gamma$= 4.5 %



The External Injection experiment @ SPARC_LAB

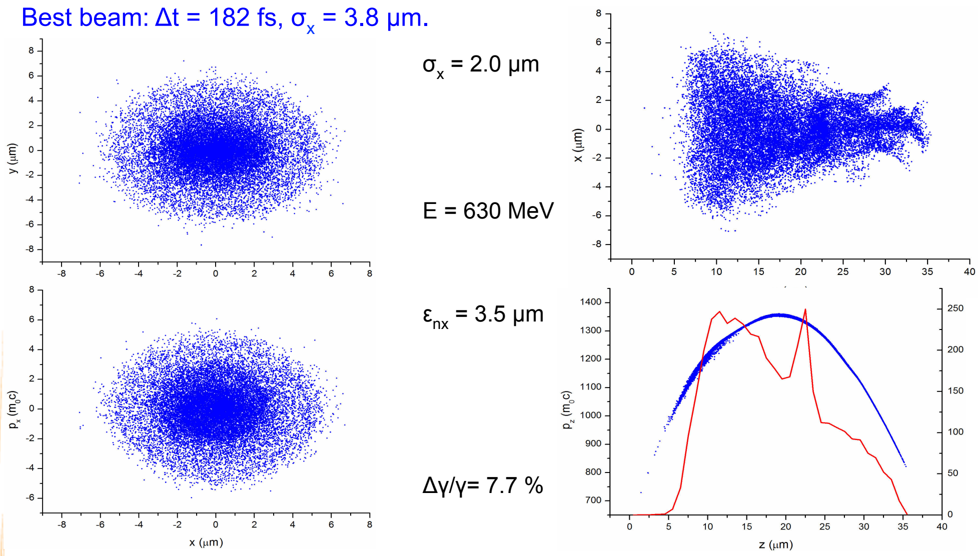
S2E simulation: plasma acceleration

Laser guided by a capillary tube: more performances but much harder to implement

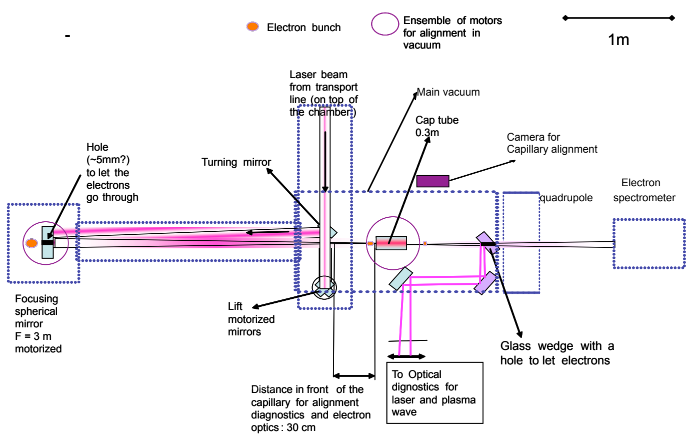


S2E simulation: plasma acceleration

Best beam: Δt = 182 fs, σ_x = 3.8 μm.

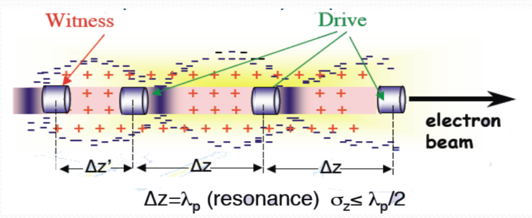


Camera di interazione



COMB_PWFA

Particle wakefield acceleration



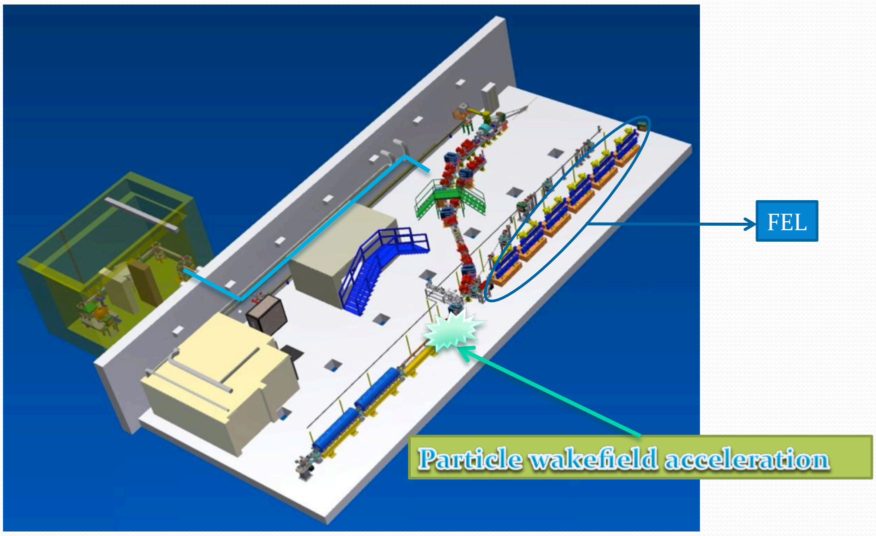
Gas ionization is externally generated (discharge or high energy electrons).

Wakefield is generated by the first bunches (comb-like structure).

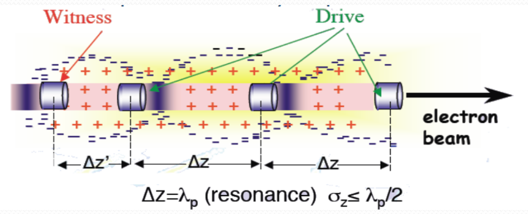
COMB-like electron bunches are injected inside the preformed plasma; The first bunches create the wakefield, which is then seen from the last bunch (witness) which will be then accelerated.

PROS: syncronization is not needed.
CONS: creation and manipolation of driver bunches and matching of all the bunches with the plasma.

Particle wakefield acceleration



Plasma parameters required in COMB



Separation between the driver bunches and the witness bunch and the length of each bunch limit the maximum plasma density up to 10^{17} cm^{-3}.

Capillary	Preassure and density	Discharge
Length: 1 to 5 cm	**Density**: 10^{15} to 10^{17} cm^{-3}	**Raising time**: ?
Diameter: 1 mm	**Preassure**: 1 to 10 mbar	**Duration**: ?
Material: any		**Voltage**: ?
Gas: hydrogen		**Current**: ?

Discharge process need to be studied!

Ionization

Plasma in our case will be generated by discharge.

To fully understand the discharge process and the plasma generation, it is of paramount importance to understand the temporal behaviour of the plasma.

To do so, we have started to find the set of equations that describe the plasma and its evolution.

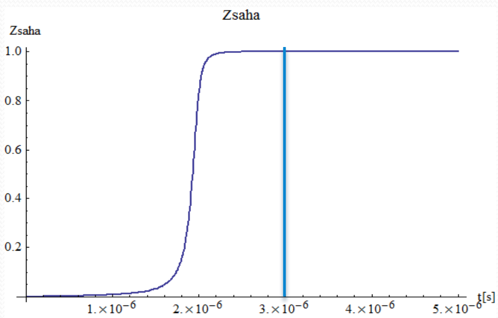
Following the literature, we have been able to write a system of equations that need to be solved to fully characterize the temporal evolution of a plasma generated by discharge.

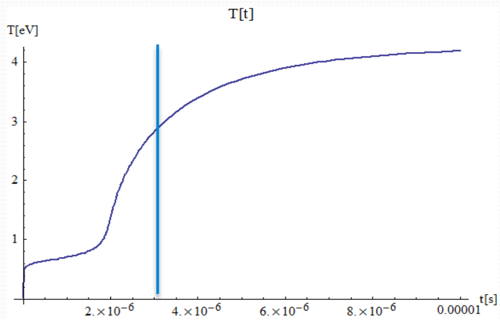
The plasma parameter that describe the plasma evolution is mainly the plasma temperature growth.

Ionization

Initial parameters:

Gas: Pressure = 10 mbar ; Density = 10^{17} cm^{-3};
RC Circuit: Voltage = 15KV; Resistance//plasma = 0.5 kOhm; Current = 20A;
Capillary: Length = 3 cm; Diameter = 1 mm;





From the analysis of the temporal trend of the ionization degree and the plasma temperature, we can see that a 3 microseconds discharge is enough to bring the gas in the state of plasma and ionize it fully.

Ionization

Using the results that we have find, we are now able to fill the discharge part of our table which was summarizing the requirements for the plasma and the discharge for the COMB experiment.

An example is the follow:

Capillary	Preassure and density	Discharge
Length: 2 cm	**Density**: 10^{17} cm^{-3}	**Raising time**: ?
Diameter: 1 mm	**Preassure**: 10 mbar	**Duration**: 100 ps
Material: any		**Voltage**: 15 kV
Gas: hydrogen		**Current**: 200 A

To estimate the rising time, we need to introduce the parasitic inductance.

This is the next step!

More details next time in M.P. Anania talk

Hamburg/Frascati first bilateral meeting on PWA

~10:30 SPARC_LAB tour

11:30 R. Assmann: Long-term ideas and interests in particular SPARC experiments (10min)

11:45 M. Ferrario: Short term planning of SPARC_LAB activities (10min)

12:00 L. Serafini/A. Rossi: External injection beam line (10min)

12:30 B. Hidding: R&D on metal vapor plasma cells and Trojan Horse scheme (10min)

14:00 B. Zeitler: The LAOLA@REGAE project in Hamburg (10min)

14:30 L. Gizzi: Self injection and Compton backscattering experiments (10min)

15:00 M. Bellaveglia: fs-Synchronization issues (10min)

15:15 F. Stephan: The DESY/Zeuthen beam modulation experiment in Berlin (10min)

15:45 R. Pompili: Characterization of COMB beam with EOS (10min)

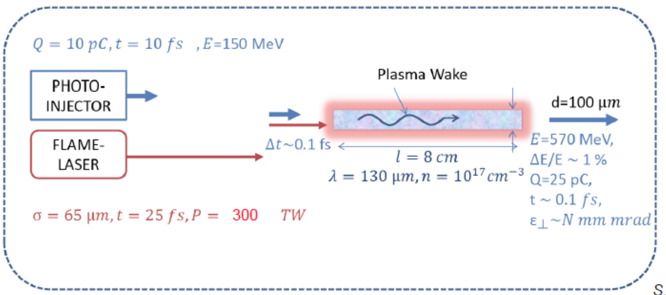
16:00 M.P. Anania: Considerations about discharge capillary requirements for COMB (10min)

16:20 D. Giulietti: Proton acceleration experiments (10min)

16:30 Final discussion

Topic: International Experiments → SPARC!?

- Discussion May 2nd at Frascati: 9 LAOLA team members went there!
- eARD interests:
  - External injection of 150 MeV beam into laser-driven plasma cell



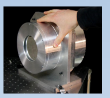
S. Sadykova

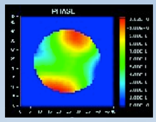
  - Resonant excitation of plasma wakefield by multiple bunches

What we wish to do now

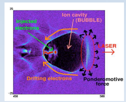
	May	June	July	Aug/Sept	Oct	Nov	Dec
Thomson	Electron Transp.	Photon Transp.	Synch. & First Collisions		Collisions	Collisions /Users	Users
FEL	Seeded 2 Colors Exp.			Inst. New Und.			Exp. With New Und.
THZ		Exp.	Exp.				
C-band	HP Test	HP Test	HP Test	Inst. on line			
Protons	Exp.						
Plasma/ Compton		Exp.					
ExInj./ Comb	Simulatio ns	EoS	Int. Chamber		Int. Chamber	Int. Chamber	Int. Chamber

PLAN OF *LPA* AT FLAME

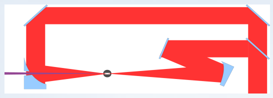




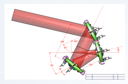
- Optical installation of full beam **adaptive optics**
  - Increase **Strehl ratio** of laser beam at full power to >0.9 (currently ≈0.3)
  - Control focal spot shape -> Control **bubble shape** in self-injection



- Self-injection run with full power and tailored focal spot on a 10 mm gas jet: currently depletion occurs at >5mm



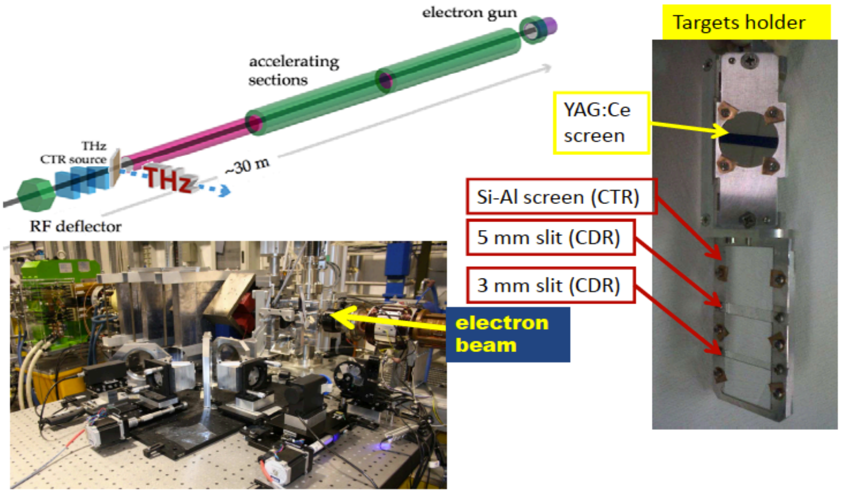
- Start assembly of two-beam configuration for **head-on collisions** (γ-Resist)



THz source

Recent Activity

New THz beamline at the Linac exit collecting both Coherent Transition (CTR) and Diffraction Radiations (CDR)



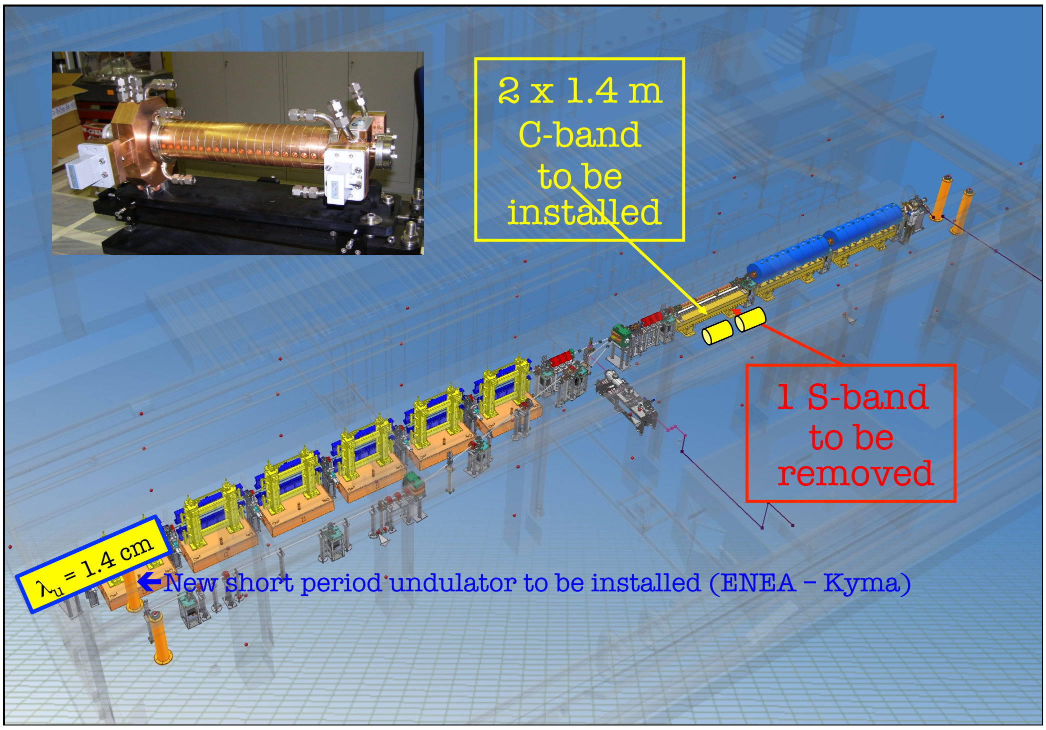
Near Future THz activity@SPARC

1) THz induced Metal-to-Insulator in V_2O_3;

2) Development of Electric Optics Sampling Single shot→ Single Shot THz Spectrum;

3) CTR and CDR comb THz radiation;

C-BAND



2 x 1.4 m
C-band
to be
installed
1 S-band
to be
removed
λ_u = 1.4 cm
New short period undulator to be installed (ENEA - Kyma)

C-band RF power line installation

-The C-band RF power line from the C-band klystron up to the SPARC hall has been completed and we are ready to start high power test. The klystron has been tesyted up to 30 MW in a 1 μs long RF pulse
-We are still waiting for the SLED pulse compression system that is under construction at IHEP (Beijing) and will be delivered by the end of June 2013.

-The high power test on the C-Band structures before their installation in the LINAC line will be done on a parallel power test line and they will not interfere with the SPARC_LAB programs.

C-band power line installed in the SPARC hall

High power test stand

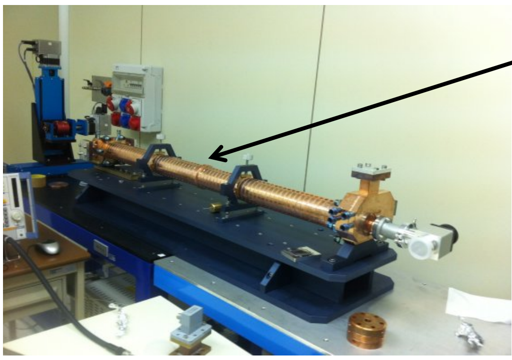
Status of C-band accelerating structure for SPARC Energy upgrade

-The first cavity has been completed but unfortunately we found a problem in the final brazing between the two half of the structure that causes a field reflection and a consequent reduction of the accelerating field.

-The mechanical drawing of the central junction has been modified and we are implementing this new design in the second structure under construction.

-The second structure will be ready by the end of May 2013.

-If we succeed in this modification we will also cut the first structure and we will modify it.



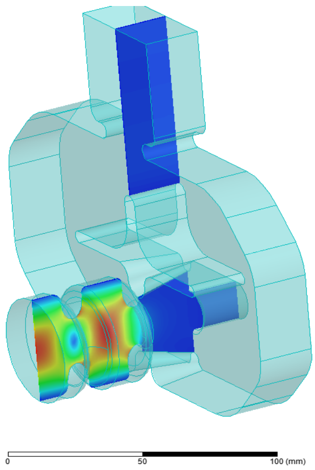
Central junction

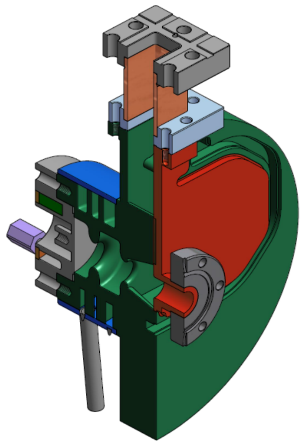
C-band RF gun status

The C-band RF gun has been designed from the electromagnetic point of view.

Mechanical design/drawings in progress.

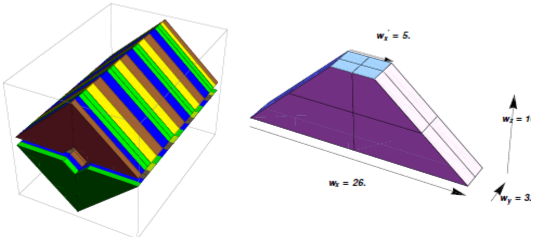
Thermal analysis for 100 Hz operation: to be done





MORE FEL

SPARC-FEL: future developments

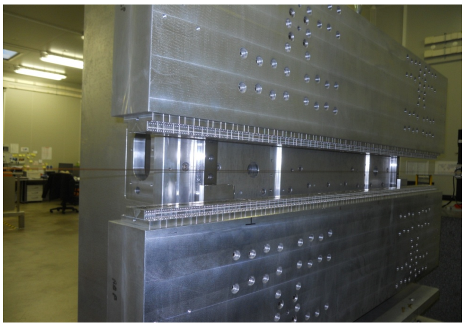


- DELTA like undulator (end of 2012)
  λu = 14.0mm, gap g = 5mm, Br = 1.22T.

  Undulator test in two possible configuration with the actual accelerator:

  1)Two stage SASE-FEL cascade:
  450nm to 150 nm

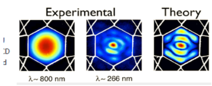
  2)Three stage seeded FEL cascade:
  400nm – 200nm – 100nm



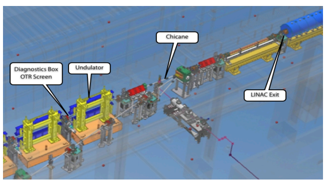
KYMA undulator

Scientific collaboration proposals

- Alternative seed sources
  Kagomé fibers
  (N. Joly, MP -
  M.E. Couprie Soleil)

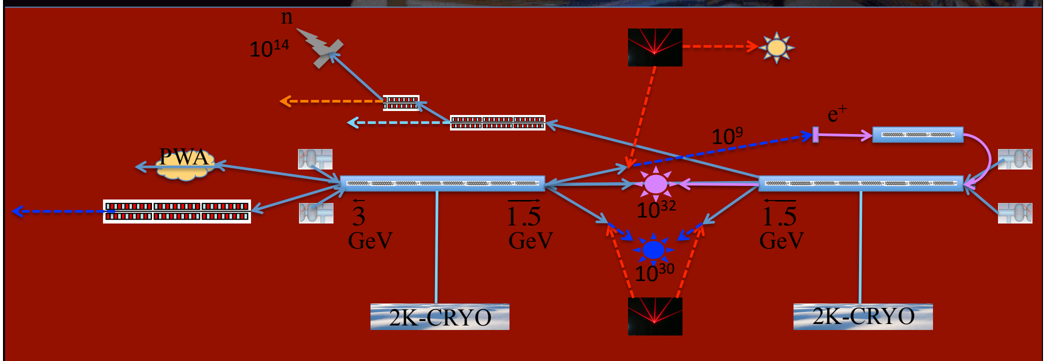


- **Experimental Study of New Effects of Noise Suppression in Relativistic Electron-Beam and Spontaneous Emission Sub-radiance in FEL** (A. Nause, A. Gover, - Tel Aviv University)



IRIDE

I R I D E is a large infrastructure for fundamental and applied physics research. Conceived as an innovative and evolutionary tool for multi-disciplinary investigations in a wide field of scientific, technological and industrial applications, it will be a high intensity "particle beams factory".



Based on a combination of a high duty cycle radio-frequency superconducting electron linac (SC RF LINAC) and of high energy lasers it will be able to produce a high flux of electrons, photons (from infrared to γ-rays), neutrons, protons and eventually positrons, that will be available for a wide national and international scientific community interested to take profit of the most advanced particle and radiation sources.

First PAC report comments

The scope of SPARC_LAB was discussed with the lab director. Due to the limited resources, SPARC_LAB should not be considered a full-fledged user facility but a test facility open to external groups. Two of such collaborations are already successfully running. To attract more, a Technical Design Report and an improved website will be prepared, which is highly welcomed. In terms of the rather substantial collaboration with ELI the pros and cons for LNF did not entirely become clear to the PAB.

SPARC_LAB PRESENT AND FUTURE

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Abstract

A new facility named SPARC_LAB has been recently launched at the INFN National Laboratories in Frascati, merging the potentialities of the former projects SPARC and PLASMONX. We describe in this paper the status and the future perspectives at the SPARC_LAB facility.

1. INTRODUCTION

A new facility named SPARC_LAB (Sources for Plasma Accelerators and Radiation Compton with Lasers and Beams) has been recently launched at the INFN National Laboratories in Frascati, merging the potentialities of the former projects SPARC [1] and PLASMONX [2]. Ten years ago in fact, a robust R&D program on ultra-brilliant electron beam photoinjector and on FEL physics, the SPARC project, a collaboration among INFN, ENEA and CNR, was approved by the Italian Ministry of Research and located at the INFN National Laboratories in Frascati.

Figure 1: Layout of the SPARC_LAB facility

The test facility is now operating, hosting a 150 MeV high brightness electron beam injector [3], able to operate also in the velocity bunching configuration [4], which feeds a 12 meters long undulator. Observations of FEL radiation in the SASE [5], Seeded [6] and HHG [7] modes have been performed from 500 nm down to 40 nm wavelength. A second beam line has been also installed and is now hosting a narrow band THz radiation source [8]. In parallel to that, INFN decided to host a 200 TW laser that will be linked to the linac and devoted to explore laser-matter interaction, in particular with regard to laser-plasma acceleration of electrons [9] (and protons) in the self injection and external injection modes. The facility will be also used for particle driven plasma acceleration experiments, the COMB [10] experiment. A Thomson back-scattering experiment coupling the electron bunch to the high-power laser to generate a quasi coherent, monochromatic X-ray radiation is also in the commissioning phase. An upgrade of the linac energy up to 200 MeV is also foreseen by the end of 2013 by installing two new high gradient C-band structures developed at LNF in the framework of the ELI_NP collaboration [18]. A layout of the facility is shown in Fig. 1.

2. HIGH POWER LASER SYSTEM

The SPARC_LAB high power laser system, named FLAME, has been recently fully commissioned. FLAME is based upon a Ti:Sa, chirped pulse amplification (CPA) laser able to deliver up to 220 TW laser pulses, 25 fs long, with a 10 Hz repetition rate at a fundamental wavelength of 800 nm, see Fig. 2.
The system features are characterized by a high contrast ratio (>10^{10}) and a fully remotely controlled operation mode. It includes a front-

2.2 Recommendations

In view of the limited resources the PAB recommends to focus on experiments of high scientific value, which can hardly be done at other places. This certainly includes experiments that need both a high-quality electron bunch and a high power laser, such as Thomson backscattering and laser plasma acceleration with external electron injection. The PAB proposes to define a priority list for the experiments.

FLAME has reported an electron acceleration of 7GV/m over 8 cm, i.e. a beam energy of some 600 MeV in the self-injection mode. To this end, laser transport into a long capillary had to be managed. While this is encouraging, it also indicates that FLAME isn't any more on the laser forefront. Other labs like Berkeley have much more powerful laser systems. The conclusion is that experiments with FLAME deserve high priority as the scientific lifetime of such devices is rather short.