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STATUS OF THE SPARC PROJECT

D.Alesini, S.Bertolucci, M. Bellaveglia, M.E.Biagini, R.Boni, M.Boscolo, M.Castellano, A.Clozza, G.Di Pirro, A.Drago, A.Esposito, M.Ferrario, L. Ficcadenti, D. Filippetto, V.Fusco, A.Gallo, G. Gatti, A.Ghigo, S.Guiducci, M.Incurvati, C.Ligi, F.Marcellini, M.Migliorati, A.Mostacci, L.Palumbo, L.Pellegrino, M.Preger, R.Ricci, C.Sanelli, M.Serio, F.Sgamma, B.Spataro, A.Stecchi, A.Stella, F.Tazzioli, C.Vaccarezza, M.Vescovi, C.Vicario, *INFN-LNF, Frascati, Italy*

F.Alessandria, A.Bacci, I.Boscolo, F.Broggi, S.Cialdi, C.DeMartinis, D.Giove, C.Maroli, M. Mauri, V.Petrillo, M.Romè, L.Serafini*, *INFN-MI and Univ. of Milano, Milano, Italy*

D.Levi, M.Mattioli, G.Medici, P. Musumeci, D. Pelliccia, M. Petrarca, *INFN-Roma1, Rome, Italy*

A. Cianchi, L.Catani, E.Chiadroni, E. Gabrielli, S.Tazzari, *INFN-Roma2, Rome, Italy*

F.Ciocci, G.Dattoli, A. Dipace, A.Doria, F.Flora, G.P.Gallerano, L.Giannessi, E.Giovenale, G.Messina, P.L.Ottaviani, S.Pagnutti, G.Parisi, L.Picardi, M.Quattromini, A.Renieri, G.Ronci, C.Ronsivalle, M.Rosetti, E.Sabia, M.Sassi, A.Torre, A.Zucchini, *ENEA-Frascati, Italy*

S. De Silvestri, M. Nisoli, S. Stagira, *Politecnico/Milano, Milano, Italy*

J.B. Rosenzweig, *UCLA - Dept. of Physics and Astronomy, Los Angeles (CA), USA*

D.H. Dowell, P.Emma, C.Limborg, D.Palmer, *SLAC, Palo Alto (CA), USA*

Abstract

The SPARC project has entered its installation phase at the Frascati National Laboratories of INFN: its main goal, the promotion of an R&D activity oriented to the development of a high brightness photoinjector to drive SASE-FEL experiments, is being vigorously pursued by a collaboration among ENEA-INFN-CNR-Universita` di Roma Tor Vergata-INFM-ST. In this paper we will report on the installation and test of some major components, like Ti:Sa laser system, RF gun and RF power system. Advancements in the control and beam diagnostics systems will also be reported, in particular on the emittance-meter device for beam emittance measurements in the drift space downstream the RF gun. Recent results on laser pulse shaping show the feasibility of producing 10 ps flat-top laser pulses in the UV with rise time below 1 ps. First FEL experiments have been proposed, using SASE, seeding and non-linear resonant harmonics.

INSTALLATION OF MAIN COMPONENTS

The SPARC project is by now in its advanced installation phase at LNF; tests of related equipments and instrumentation are also under way. The 150 MeV S-band photo-injector and the 12 m undulator for the FEL experiments are located inside an underground bunker, which hosts as well the clean room containing the Ti:Sa laser system driving the photo-cathode. As discussed elsewhere [1], the project aims at conducting a bouquet of advanced experiments in the production, characterization and control of high brightness electron beams, as those required by X-ray FEL's and advanced high gradient acceleration techniques (plasma, IFEL, etc.).

Figure 1: Layout of SPARC photo-injector, with RF-gun, 3 S-band accelerating sections and FEL undulator (6 modules). Beam line for undulator by-pass is also shown.

The layout of the machine, shown in Fig.1, displays a RF-gun, 3 S-band SLAC-type accelerating sections, and a 6-module 12-m long undulator for SASE and seeded FEL experiments in the 88-500 nm wavelength range.

The installation of the RF source and distribution system started last month. The klystron pulsed power modulators, supplied by PPT, have been positioned in the SPARC klystron hall, as well as the klystrons (45 MW,

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2856 MHz, TH2128C model manufactured by Thales), as shown in Fig.2. The modulator connections with various controls and ancillary systems are being made. Modulators can switch the klystrons at a maximum rep. rate of 10 Hz, with HV pulses of 310 kV – 340 A.

The modulator power test, scheduled at the end of this month, will be performed initially with the klystron operating in diode-mode. The installation of waveguide distribution network and RF devices (circulators, shifters, etc.) will begin next month.

Figure 2: SPARC klystrons with oil tanks installed in the SPARC building (upper facility room or klystron hall).

The 1.6-cell RF gun and the emittance-compensation solenoid have been delivered at LNF in February from UCLA [2]. The gun supports are being modified to gain full control of the gun axis alignment. The water flow into the gun has been measured up to 5 l/m, a value that should allow control of the gun temperature at the level required for operation up to 10 Hz. The magnetic solenoid yoke has been assembled and it is also going through some minor mechanical modifications. The solenoid uses 4 different coils that can be independently excited. The magnetic field will be measured to check for axis misalignments and to record longitudinal magnetic field profiles in the different current configurations. The full system should be fully tested, mounted and aligned by mid summer and ready for RF power tests in September.

Two accelerating sections will be delivered next July by Mitsubishi, while one of the two sections given by SLAC to SPARC, as part of a collaboration agreement, is under test. As shown in Fig.1, the first accelerating section will be embedded (see yellow zone) in an array of solenoids, required to produce a magnetic field for additional focusing in order to comply with the Ferrario working point[3] matching conditions for emittance compensation. Thanks to a newly funded European project, EUROFEL, an additional array of solenoids will be built and installed around the second section, in order to further improve the performances of emittance compensation in particular when RF compression is applied [4].

The Ti:Sa laser system, built by Coherent, is now under final acceptance tests. The oscillator is already installed inside the clean room in the SPARC bunker, while the amplifier is being shipped by Coherent to LNF for final acceptance tests of the whole laser system: these will be conducted next month at LNF. The HIDRA-50 amplifier system, made of one regenerative and two multi-pass amplifiers, has already reached the specs in the infra-red, delivering 50 mJ of output pulse energy with 104 fs pulses and good beam quality (M^2_x=1.9 and M^2_y =1.6). Preliminary tests in the UV (266 nm), performed after the third harmonic crystal and the UV stretcher, showed the capability to reach 1.8 mJ of pulse energy with quite good pulse-to-pulse stability, *i.e.* less than 4.5%, and a fairly good beam quality, *i.e.* M^2_x=2.7 and M^2_y =1.9 . These tests will be further completed at LNF soon.

Figure 3: HIDRA-50 amplifier for the SPARC laser.

A preliminary measurement of the time jitter between the laser oscillator and an external reference 79 MHz RF wave was performed at LNF. The signal from a photodiode looking at the optical pulse train, properly filtered and amplified, was mixed with a portion of the 79 MHz wave driving the oscillator phase-locking loop.

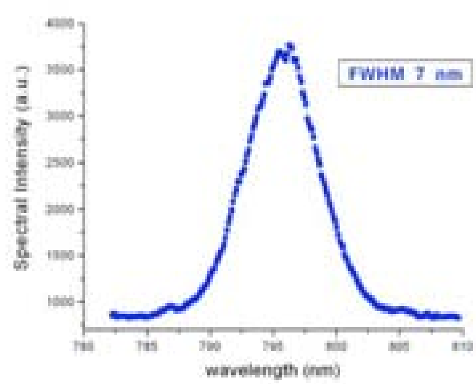

Figure 4: Output spectrum of laser oscillator.

The relative phase between the two signals was measured by monitoring the mixer output: an upper limit of 1.4 ps was found. A characterization of the oscillator output spectrum was also performed, showing a quite good behavior (see Fig.4).

The emittance-meter device has been completed, as shown in Fig.5, and is ready to be installed in the drift line after the RF gun and focusing solenoid system, in order to conduct measurements of the rms normalized transverse emittance as a function of the drift length. This measurements will be performed at the beginning of next year running the beam at the RF-gun exit energy of 5.7 MeV, before installation of the 3 accelerating sections.

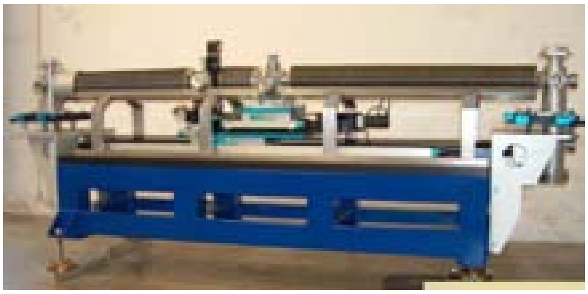

Figure 5: Emittance-meter device with long bellows.

BEAM DYNAMICS STUDIES

Beam dynamics studies have moved further than previously reported[1]. The study of beam quality achievable using Gaussian laser pulses has been performed[5], while the ultimate beam brightness achievable applying RF compression in the SPARC photo-injector, reported in [4], is shown to reach a record value of $1.1 \cdot 10^{14}$ A/(m.rad)^2 , implying a peak current up to 1 kA with a normalized slice transverse emittance (in the central part of the bunch) of 0.5 μm.

R&D ACTIVITY

Laser Pulse Shaping

Previous measurements of laser pulse shaping using the Dazzler were reported in [1], showing promising results. A more complete experiment involving electron bunch production with shaped laser pulses was conducted at BNL-DUV by a SPARC-SLAC-BNL/DUV collaboration, and is reported in [8]. An R&D activity on laser pulse shaping with LCM masks is also in progress and will eventually be integrated in the SPARC laser system.

X-band cavities

The design and realization of an X-band accelerating section for linearizing the longitudinal phase space of the SPARC beam is under way. The structure, operating on the π standing wave mode, is a 9 cell structure fed by a central coupler and is designed to achieve 42 MV/m accelerating gradient. Bead-pull measurements performed on a copper prototype at room temperature were in very good agreement with numerical predictions. Mechanical details of the realized prototype and RF properties of the structure as a function of the assembly characteristics are discussed in more details in [6].

*Luca.Serafini@mi.infn.it

FEL EXPERIMENTS

SPARC participates to the EUROFEL programme also in the seeding experiments work package. We foresee the installation of a chamber for generating short pulses (few tens of fs) of high order harmonics of the Ti:Sa generated in gas (266nm, 160 nm, 114nm, 88nm), and to feed the FEL amplifier with this seed pulse. The chamber and the related hardware will be provided by the CEA-SPAM (Service de Photons, Atomes et Molécules) which also participate to the experiment through the EUROFEL framework. Diagnostics of the output radiation in terms of spectrum and pulse duration will provide relevant information about the FEL amplification process. The SPARC radiation will be monitored by diagnostic stations located in between the six undulator sections to follow the dynamics of the pulse propagation in different FEL regimes, from the shot noise to the exponential growth, to the saturation and beyond.

CONCLUSIONS

Main components of the SPARC project are under installation and test: we expect to conduct the first beam emittance-meter experiments during the first months of next year. The first beam at full energy out of the Linac is due within June 2006. The SPARC system will be upgraded during the next 5 years to become an advanced accelerator facility as described in [7].

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