CARE/JRA2: 1nd and 2nd Quarterly Report 2006

Title: Charge production with Photo-injectors

PHIN **Coordinator: A. Ghigo (INFN-LNF)**

Deputy: R. Losito (CERN)

Participating Laboratories and Institutes:

Institute	Acronym	Country	Coordinator	PHIN Scientific Contact	Associated to
CCLRC Rutherford Appleton Lab. (20)	CCLRC-RAL	UK	P. Norton	G. Hirst	
CERN Geneva (17)	CERN	CH	G. Guignard	R.Losito	
CNRS-IN2P3 Orsay (3)	CNRS-Orsay	F	T. Garvey	G. Bienvenu	CNRS
CNRS Lab. Optique Appl. Palaiseau (3)	CNRS-LOA	F	T. Garvey	V. Malka	CNRS
ForschungsZentrum ELBE (9)	FZR-ELBE	D	J. Teichert	J. Teichert	
INFN-Lab. Nazionali di Frascati (10)	INFN-LNF	I	S. Guiducci	A. Ghigo	INFN
INFN- Milan (10)	INFN-MI	I	C. Pagani	I. Boscolo	INFN
Twente University- Enschede (12)	TEU	NL	J.W.J. Verschuur	J.W.J. Verschuur	

Main Objectives: Perform Research and Development on charge-production by interaction of laser pulse with material within RF field and improve or extend the existing infrastructures in order to fulfil the objectives. Coordinate the efforts done at various Institutes on photo-injectors.

Cost:

Total Cost	Requested Cost
3.851 M€(FC) + 2.150 M€(AC) Total = 6.001 M€	**3.542 M€**

1. Management activities

1.1 Meeting:

SRF gun collaboration meeting on March 24, 2006 at FZR, Dresden

SRF gun collaboration meeting on July 24, 2006 at BESSY, Berlin

CERN – RAL Visit (technical discussions) 15 to 18/8/2006

CERN – LAL Meeting (technical discussions): 13/09/2006

INFN – LOA Meeting on "Future INFN-LOA collaboration on plasma acceleration: PHIN evolution"

2. Dissemination of Activity.

2.1 List of talks and conference contributions

1- Cs_2Te Photocathodes for CTF3 Photoinjectors, R. Losito Workshop on High QE Photocathodes for RF Guns, INFN-LASA, 4 to 6/10/2006

2- Development of a Superconducting RF Photoelectron Injector
J. Teichert
DPG-Tagung, Vacuum Science and Technology, Dresden, Germany, March 27, 2006

3- Advantages of the superconducting 3 1/2 cell gun at Rossendorf
F.Staufenbiel, A. Arnold, H. Büttig, P. Evtushenko, D. Janssen, U. Lehnert, P. Michel, K. Möller, P. Murcek, Ch. Schneider, R. Schurig, J. Teichert, R.Xiang, J. Stephan, W.-D. Lehmann, T. Kamps, D. Lipka, I. Will, V. Volkov
37th ICFA workshop, Hamburg, Germany, May 15-18, 2006

4- 3-1/2 Cell Superconducting RF Gun Simulations
C.D. Beard, J.H.P. Rogers, F. Staufenbiel, J. Teichert,
EPAC 2006, Edinburgh, Scotland, June 26 – 30, 2006

5- Progress of the Rossendorf SRF Gun Project
D. Janssen, A. Arnold, H. Buettig, R. Hempel, U. Lehnert, P. Michel, K. Moeller, P. Murcek, Ch. Schneider, R. Schurig, F. Staufenbiel, J. Teichert, R. Xiang, T. Kamps, D. Lipka, F. Marhauser, W.-D. Lehmann, J. Stephan, V. Volkov, I. Will,
EPAC 2006, Edinburgh, Scotland, June 26 – 30, 2006

6- Photocathode Laser for the Superconducting Photo Injector at the Forschungszentrum Rossendorf
I. Will, G. Klemz, F. Staufenbiel, J. Teichert,
FEL 2006, Berlin, Germany, Aug. 27 – Sept. 01, 2006

7- Cryomodule and Tuning System of the Superconducting RF Photo-Injector
J. Teichert, A. Arnold, H. Buettig, R. Hempel, D. Janssen, U. Lehnert, P. Michel, K. Moeller, P. Murcek, Ch. Schneider, R. Schurig, F. Staufenbiel, R. Xiang, T. Kamps, D. Lipka, G. Klemz, W.-D. Lehmann, J. Stephan, I. Will,
FEL 2006, Berlin, Germany, Aug. 27 – Sept. 01, 2006

8- First RF-Measurements at the 3.5-Cell SRF-Photo-Gun Cavity in Rossendorf
A. Arnold, H. Buettig, D. Janssen, U. Lehnert, P. Michel, K. Moeller, P. Murcek, Ch. Schneider, R. Schurig, F. Staufenbiel, J. Teichert, R. Xiang, T. Kamps, D. Lipka, F. Marhauser, G. Klemz, W.-D. Lehmann, A. Matheisen, B. van der Horst, J. Stephan V. Volkov,
FEL 2006, Berlin, Germany, Aug. 27 – Sept. 01, 2006

9- Laser plasma accelerators
V. Malka (plénière), Advanced Accelerators Concepts, July 10-14, Lake Geneva, Wisconsin (2006).

10- Desing, test and premise of laser plasma accelerators
V. Malka, (plénière) European Particle Acceleration Conference, June 26-30, Edimbrugh, UK (2006).

11- Compact laser plasma accelerators for science and society
V. Malka, “Many-Particle Dynamics and Precision Spectroscopy: Trends and Applications”, March 30-31, Heidelberg (2006).

12- Laser-plasma wakefield acceleration: concepts, tests and premises
V. Malka, J. Faure, Y. Glinec, A. Lifschitz, European Particle Accelerator Conference EPAC, Edimburgh, June 26-30 (2006)

13- Production and applications of quasi mono energetic electron bunches in Laser-plasma accelerator
Y. Glinec, V. Malka, J. Faure, A.F. Lifschitz, Superstrong Fields in Plasma, AIP Conf. Proceedings 827 (2006).

14- Simulations of pre-modulated e-beams at the photocathode of a high brightness rf-photoinjectors
M. Boscolo, M. Ferrario, C. Vaccarezza, I. Boscolo, F. Castelli, S. Cialdi, EPAC Conf. Edinburg UK, 2006 MOPCH025.

15- Production of flat top UV pulse for SPARC photoinjector
C. Vicario, A. Ghigo, G. Gatti, M. Petrarca, P. Musumeci, I. Boscolo, S. Cialdi; EPAC Conf. Edinburg UK, 2006.

16- Commissioning of the laser system for SPARC photoinjector
C. Vicario, A. Ghigo, G. Gatti *(INFN/LNF)*, M. Petrarca, P. Musumeci *(INFN-Roma1)*.
EPAC Conf. Edinburg UK, 2006

2.2 List of publications

1- Test of the photocathode cooling system of the 31/2 cell SRF gun
F. Staufenbiel, H. Büttig, P. Evtushenko, D. Janssen, U. Lehnert, P. Michel, K. Möller, Ch. Schneider, R. Schurig, J. Teichert, R. Xiang, J. Stephan, W.-D. Lehmann, T. Kamps, D. Lipka, I. Will, V.Volkov
Physica C 441 (2006) 216-219

2- Technology challenges for SRF guns as ERL sources in view of Rossendorf work
D. Janssen, H. Buettig, P. Evtushenko, U. Lehnert, P. Michel, K. Moeller, P. Murcek, Ch. Schneider, R. Schurig, F. Staufenbiel, J. Teichert, R. Xiang, J. Stephan, W.-D. Lehmann, T. Kamps, D. Lipka, V. Volkov, I. Will,
Nucl. Instrum. Meth. Phys. Res. A **557** (2005) 80

3- Untersuchung zur Feldverteilung verschiedener Moden in mehrzelligen Beschleunigerresonatoren,
André Arnold,
Diploma Thesis, Technical University of Dresden, January 2006

4- Laser-plasma wakefield acceleration: concepts, tests and premises
V. Malka, J. Faure, Y. Glinec, A. Lifschitz, to be published to PR -STA

5- Absolute calibration for a broadrange single shot electron spectrometer
Y. Glinec, J. Faure, A. Guemnie-Tafo, V. Malka, H. Monard, J.P. Larbre, V. De Waele, J.L. Marignier, M. Mostafavi, to be published in RSI.

6- Ultra short laser pulses and ultra short electron bunches generated in relativistic laser plasma interaction.
J. Faure, Y. Glinec, G. Gallot, and V. Malka, Phys. Plasmas 13, 056706 (2006).

7- Design of a compact GeV Laser Plasma Accelerator
V.Malka, A. F. Lifschitz, J. Faure, Y. Glinec, NIM A 561, p310-131 (2006)

8- Wakefield acceleration of low energy electron bunches in the weakly nonlinera regime
A. F. Lifschitz, J. Faure, Y. Glinec, V. Malka, NIM A 561, p314-319 (2006)

9- Proposed Scheme for Compact GeV Laser Plasma Accelerator
A. Lifschitz, J. Faure, Y. Glinec, P. Mora, and V. Malka, Laser and Particle Beams 24, 255-259 (2006)

10- Radiotherapy with laser-plasma accelerators: application of an experimental quasi-monoenergetic electron beam
Y. Glinec, J. Faure, T. Fuchs, H. Szymanowski, U. Oelfke, and V. Malka, Med. Phys. 33, (1) 155-162 (2006)

11- Laser-plasma accelerator: status and perspectives
V. Malka, J. Faure, Y. Glinec, A.F. Lifschitz, Royal Society Philosophical Transactions A, 364, 1840, 601-610 (2006)

12- High third harmonic flat pulse laser
S. Cialdi, M. Petrarca ,C. Vicario Generation Opt. Lett. 31, 19 (2006) 2885

3. Status of the work

WP 2, CHARGE PRODUCTION

CERN

In the first part of 2006 most of the work for refurbishing the installations of the photocathode laboratory has been completed. Only a few components (i.e. a wall current monitor) and some control software need to be finished.

The DC Gun, used to pre-qualify the photocathode performance was baked out till a pressure close to 10^{-10} mbar was reached. After that operation it was possible to condition the Gun up to its nominal field of 10 MV/m with a copper photocathode (without any photosensitive film). This process was repeated with a photocathode with a bulk quartz substrate to prove that no problems arise with such material, in view of the possible use of Secondary Emission Yield photocathodes. Fig. 1 shows the profile of vacuum level during conditioning.

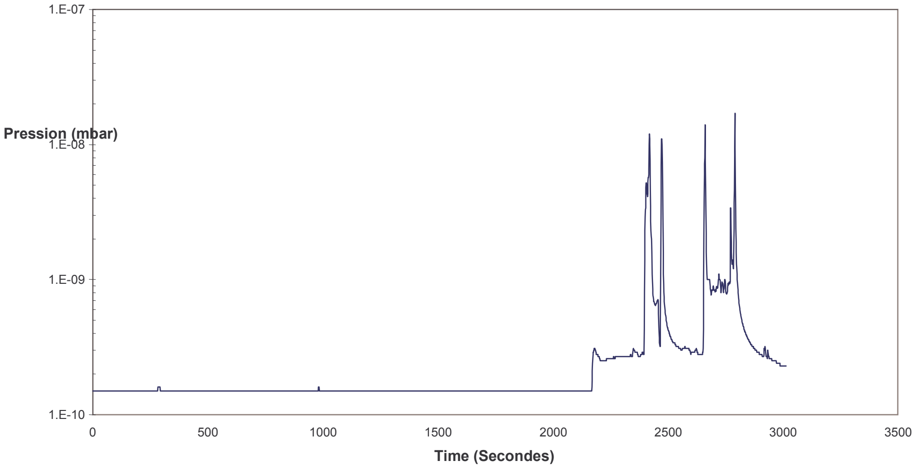


Fig. 1: Diagram of pressure inside the DC Gun during conditioning.

The integration of the RF Gun into the layout chosen for the off-line test has been fixed and drawn in 3D to check for interferences (see fig. 2). Several problems of incompatibility among the different parts of the photoinjector and measurement line have been solve thanks to detailed modelisation.

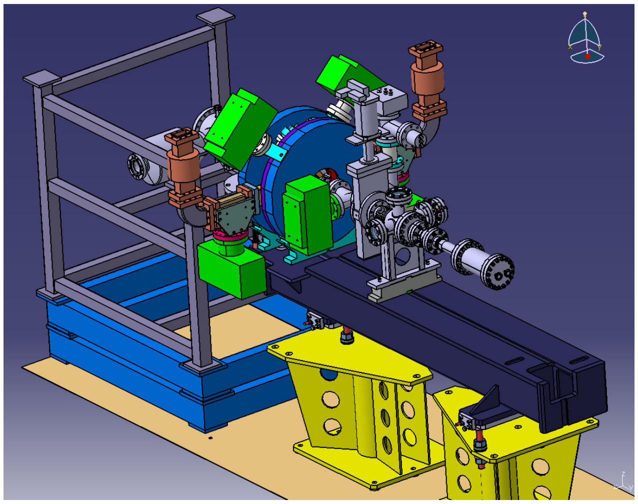


Fig. 2: Integration layout of the photoinjector.

With the deposition chamber fully refurbished, and intense campaign of calibration of the different sensors has started, In particular, to ensure a good reproducibility of the Quantum Efficiency of the photocathodes in Cs_2Te an intense campaign of calibration of the different sensors included in the chamber is on-going. The most significative technique in our installation is to read the thickness directly on two independent quartz microbalances positioned in the vicinity of the photocathode during deposition. A 3D study has been carried out to determine convenient masks to apply during the deposition process to protect the Te balance from Cs and viceversa. The masks have been simulated with CATIA and then realized, and according to our first measurements the rejection of the unwanted species is better than a factor 150. The masks are shown in fig. 3-6.

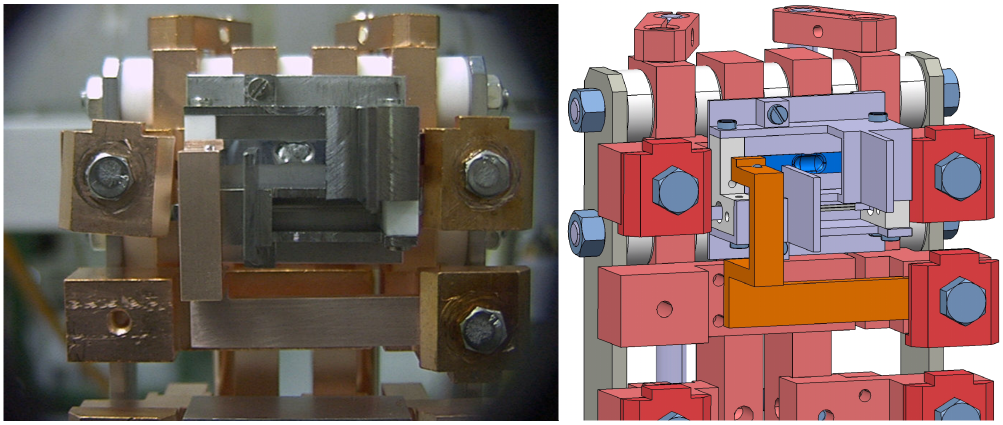


Fig. 3: A picture and the 3D drawing of the deposition ovens and the masks to protect the microbalances.

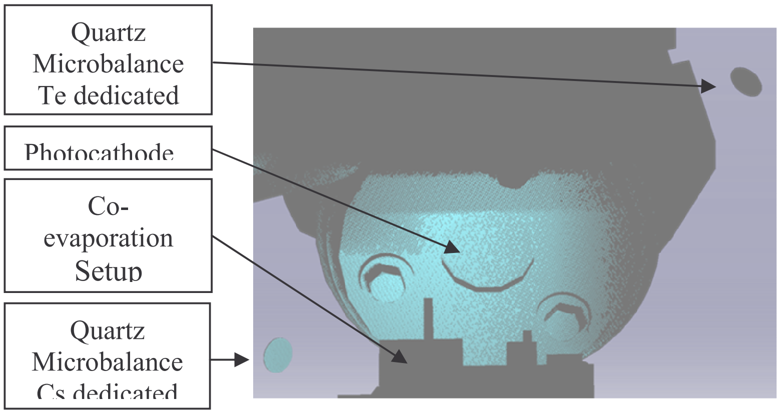


Fig. 4: the deposition set-up designed with CATIA in 3D to determine the deposition profile. It can be noticed that only one microbalance is illuminated by the active oven (the one containing Cesium).

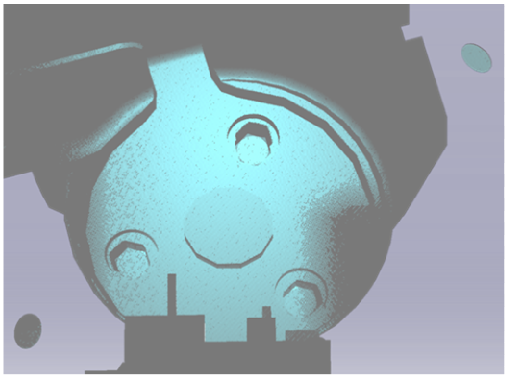


Fig. 5: Activating only the oven containing Tellurium, now it is the other microbalance that sees the deposition vapor.

After verification of the independence of the measurements from the unwanted element, the calibration of the measurements given by the microbalances has started. Several photocathodes were deposed with only one element, then the thickness of the thin film measured with different techniques:

1) special photocathodes made of quartz have been deposed to measure the optical transmission of the sample. Though this measurement does not give an absolute measurement of the thickness of the film, it allowed to otimise the shape of the mask to maximize the quantity of elements arriving to the photocathode. In fig. 6 and 7 measurments of Te deposition for two different masks are presented. In the second, the shape of the mask has been modified to increase the quantity of tellurium on the microbalance for a given measurement on the photocathode.

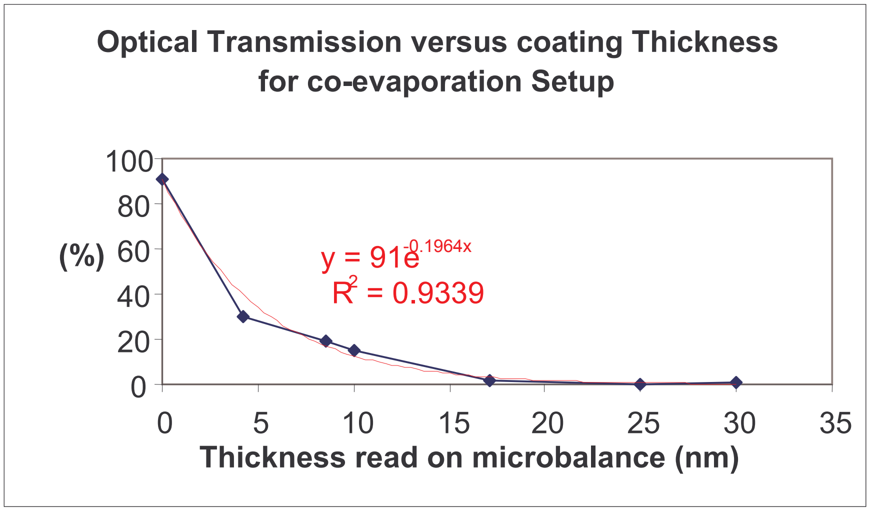


Fig. 6

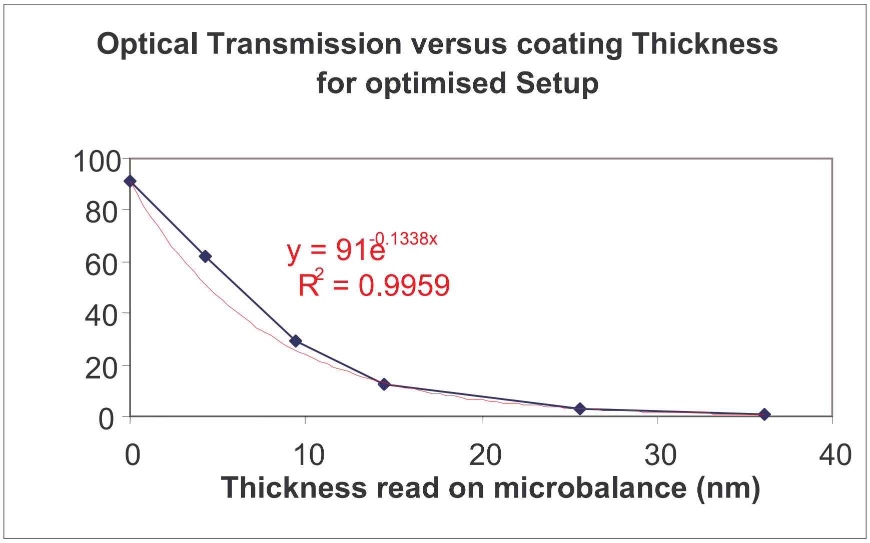


Fig. 7

2) Measurement of absolute thickness using a precision rugosimeter. A new rugosimeter has been installed in the CERN metrology department. The theoretical measurement accuracy is 0.1 nm. Some test measurements have already been performed, but several tricks need to be implemented to get a significative measurement with the desired accuracy. Intensive work of measurement will be performed during the second part of the year.

In the second part of 2006 CERN made progress in the understanding of the process of deposition of Cs_2Te photocathodes in the CERN photocathode laboratory. In order to get repeatable results the control of the stoichiometric ratio is fundamental. In CERN's laboratory this is pursued by the control of the thickness of the deposed elements on two quartzes whose change in resonant frequency is monitored and correlated with the film deposed on the photocathode, measured independently with special profilers. During the calibration of this methode, we discovered that the quantity of Te deposed on the corresponding quartz was changing with time, and we correlated the integrated thickness deposed on the different samples with the actual measurement from the quartz. Instead of a straight line, as we get on

Quartz 1, we have an exponential decrease on Quartz 2. We explained that decrease with geometrical consideration. In Practice, as the boat containing the Te compound empties, the quartz is little by little masked by the boat geometry, therefore the quantity of Te seen by the quartz is changing with respect to the quantity deposed on the photocathode.

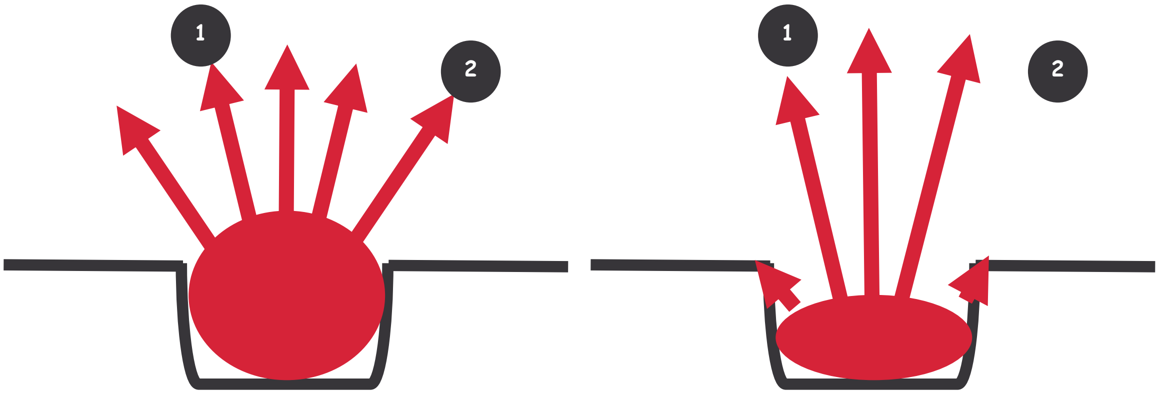


Fig. 1: The quantity of Te seen by Quartz 2 diminishes over time due to the geometry of the boat and to the relative position of the quartz with respect to the Photocathode.

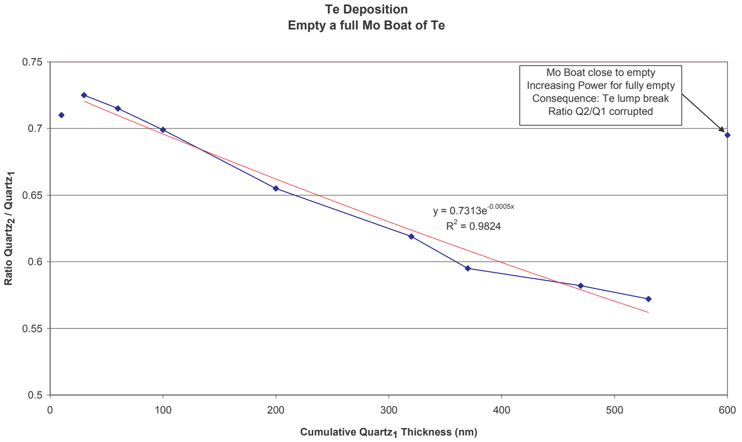


Fig. 2: Calibration of Quartz 2 vs Quartz 1. Ideally we should see a line parallel to the abscissa.

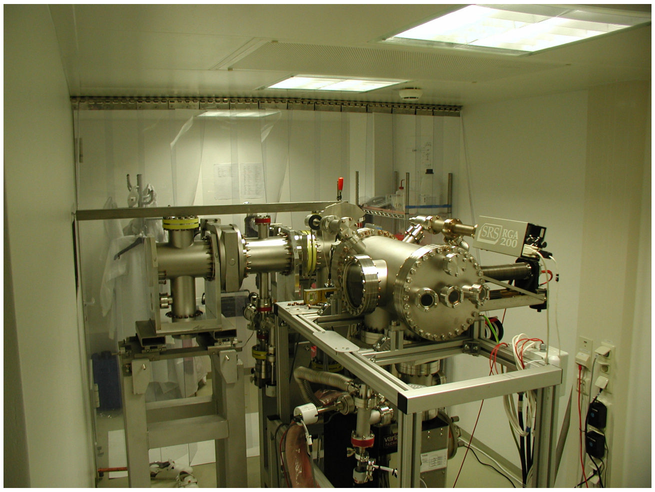
In order to further characterize the system and refine and speed –up the thickness measurements, a mechanical stylus profiler with nanometer resolution has been purchased and will be available for operation at the end of the year.

CERN has also extensively collaborated with LAL in order to finalize the integration of the RF Gun into the CTF2 environment. Several technical decisions have finally been taken concerning pumping of the gun and of the waveguides and installation procedures. CERN has also started simulations of the gun to verify the thermal stability of the gun for operation at 50 Hz.

Finally, an important milestone has been reached, with the delivery to CERN of all the components of the laser. Though not all the performances of the laser were proven at RAL, it was decided anyway to transfer the system to CERN (what was done of August 28th) and the assembly is now going on in the CTF2 laser room. An associate previously working on this laser at RAL has been hired for 6 months to complete the installation and commissioning of the laser.

FZR

The photocathode preparation system has been installed in the clean room now. It is connected to control electronics and the control PC. Complete remote-controlled and parameter recording is realized. The transfer and storage systems for the photo cathodes were assembles, tested and installed in the clean room. A second transfer and storage system is fabricated and will later be installed at the SRF gun. The preparation system was improved by means of a precise positioning system for the evaporators. In spring a delay in photo cathode technology work was happened due to the pregnancy leave of the responsible co-worker. Since July, this work has been continued and the lost time will be regained.

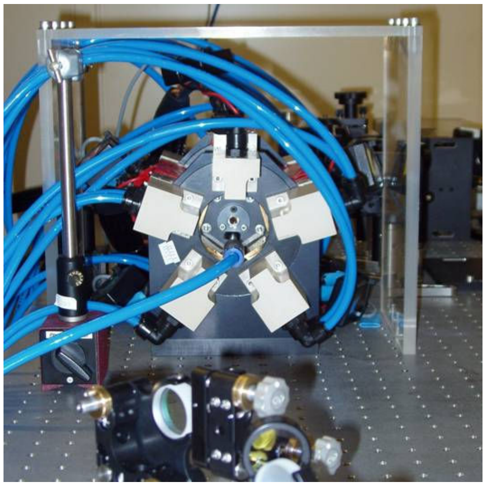


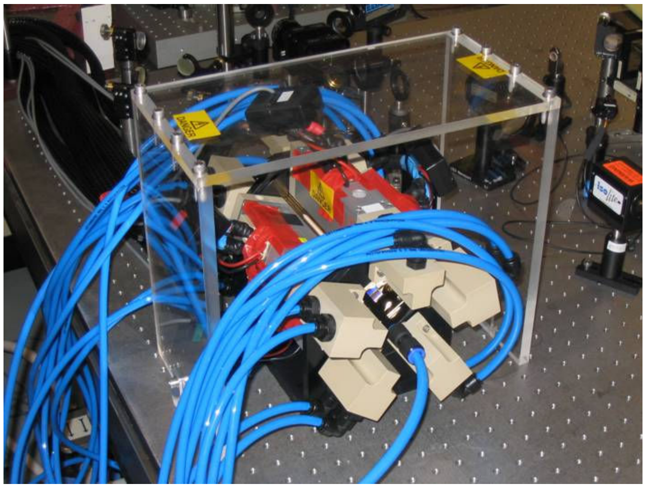
Photograph of the preparation chamber and transfer system in the clean room at FZR.

WP3, LASER

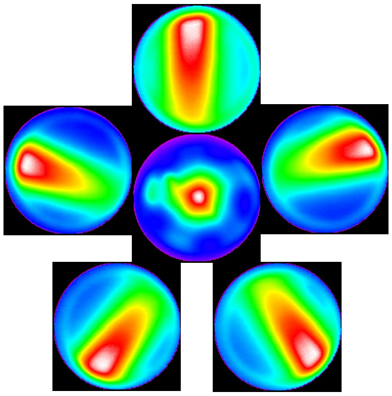
RAL

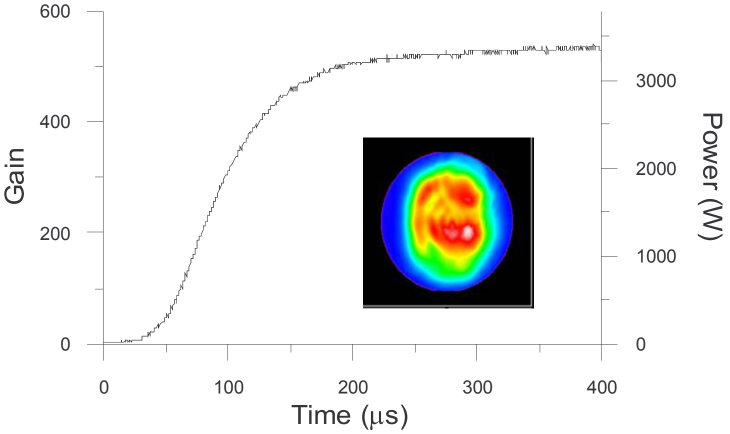
All the laser system components have been tested in the final conditions and shipped to CERN for the installation and final test. The two multi-pass amplifiers almost achieved the final energy per pulse and the amplitude stability along the pulse trains.



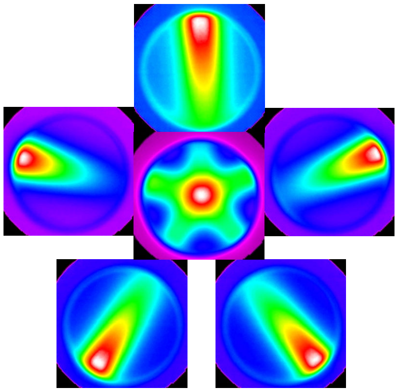


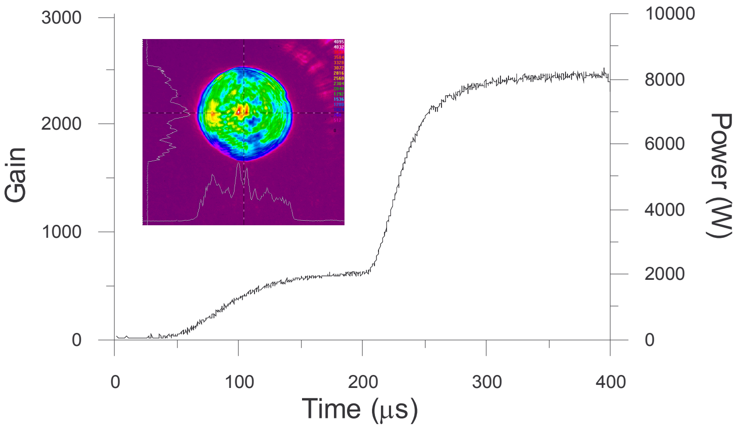
The test of the first amplifier has been performed at 10 and 50 Hz repetition rate and the measured output exceeds target power (3 kW from 3 passes). Output saturates in agreement with model and as shown below the pumping arrangement delivers good uniformity across the rod. Near-field profile is flattened by saturation but shows some effects of rod inhomogeneities





Second amplifier has been tested up to more than 8kW: 10kW from Amp 2 corresponds to 6.7mJ/pulse. Uniformity is good but the rod is underfilled

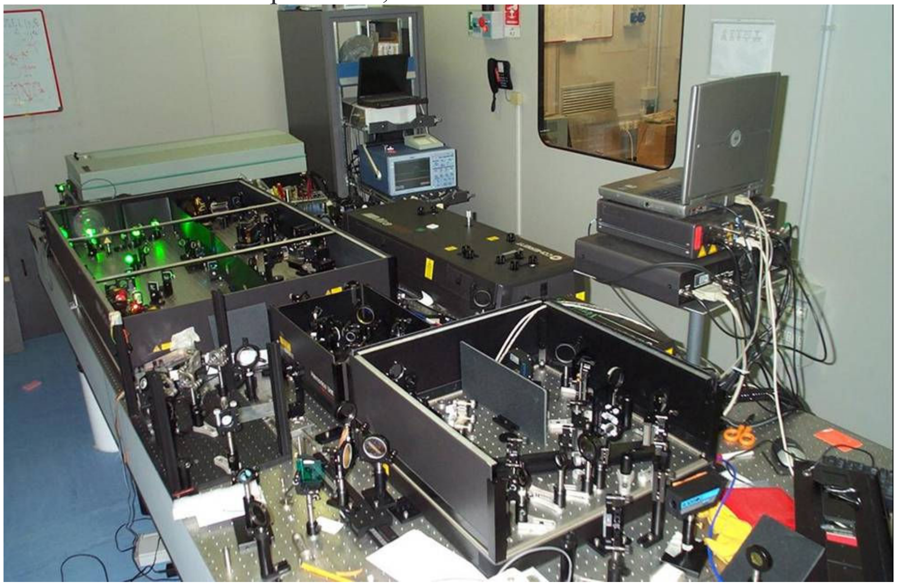




The pulse coding system has been also developed; fibre modulation, based on telecommunication technology, is fast but lossy and limited in average power.
Measurements on the High Q system suggest 10dB loss before the preamp results in <3dB output reduction. Delay can be adjusted by varying the fibre temperature (~0.5ps/°C) Attenuation can be controlled by varying the fibre bending losses Preliminary assembly and tests of temperature tuning were carried out at RAL

INFN - LNF

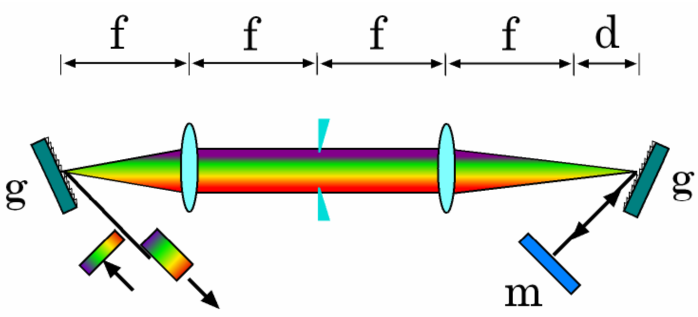
In the frame of the Care collaboration, the research program of temporal pulse shaping is in progress at the SPARC laser system in LNF-INFN. The target time profile is an uniform UV pulse with less than 1 ps rise time and with limited ripple (<30% ptp).
The SPARC Ti:SA laser system has been integrated with an active temporal pulse shaper based on an acousto-optic filter, named Dazzler.

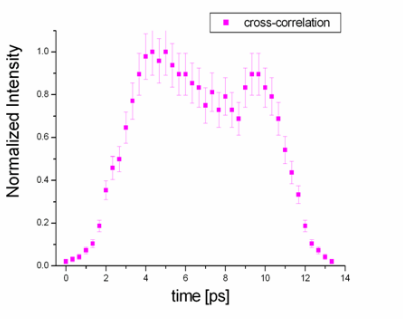


The pulse shaper was installed between the oscillator and the amplification stage. Several measurements have been performed to demonstrated the capabilities and the limitations of the filter. In particular the alterations on the pulse profile, due to the chirped pulse amplification (CPA), has been investigated. It came out that the usual distortion associated with the amplifiers, such as frequency red-shift and saturation effect, can be effectively compensated by the Dazzler. On the other hand the filter can not balance the smoothing of the rise time introduced by the CPA.

The distortions due to the third harmonic generation (THG) have been extensively characterized. In particular, the measurement of the harmonic spectra as function of the input pulse spectral phase has been carried out. In fact, sn important point is that the harmonic spectra tends to reproduce the IR only for large IR chirp. Approaching the transform-limited condition, the harmonic spectra tend to a triangular shape with narrow bandwidth. In this situation, the laser IR spectrum experiences strong distortions that cannot be compensated by the pulse shaper. We investigated the input chirp value to have enough TGH efficiency and generate UV square-like spectra. In fact, this is critical to obtain a square temporal laser profile, because in our configuration, where a large chirp is applied by an UV stretcher downstream the THG, the final time profile reproduces the spectral intensity. The correlation between spectrum and time intensity has been experimentally confirmed using two homebuilt diagnostic tools: a spectrometer and an UV cross-correlator.

The shaped pulses obtained are uniform with rise time less than 2.5 ps and ripple limited to 20 % ptp. The rise time is worse than the required one. Optical simulations show that better profile can be achieved by using a spectral filter within the UV stretcher. This solution has been implemented cutting the side frequencies in the dispersed spectrum performing a better rise time (1ps)





.

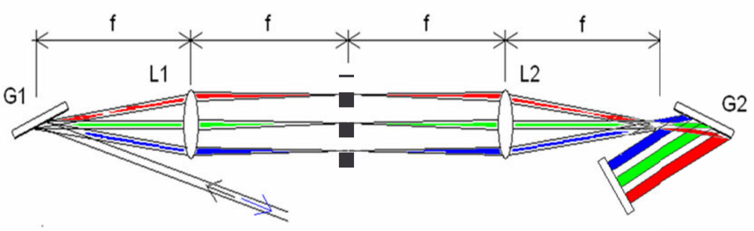
In parallel with the AO filter a pulse shaper, based on a liquid crystal mask in the 4-f configuration, has been installed. The 4-f optical system has been designed and mounted. In the next future the two pulse shaping techniques are going to be compared.

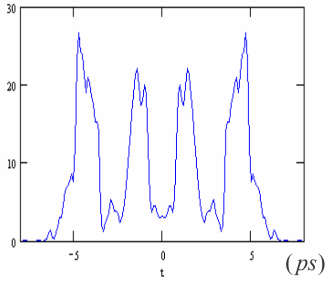
Besides, experimental work is in progress to measure the jitter between the rf clock and the UV laser pulse. The actual results demonstrate a good laser stability within the SPARC specs (0.65 ps rms). This value take into account also the jitter of the measurement equipment and unwanted electrical noise. Further experimental activities are foreseen to quantify the real jitter between the laser and the rf master clock.

INFN - MI

We worked mostly at the SPARC-Frascati experiment in setting the 4f-system for the generation of the rectangular laser pulse within the laser system of the SPARC project and for comparison with DAZZLER system. The shaping system within the entire laser system has been designed and assembled according the proper spectral configuration and the successive longitudinal modulation via the stretcher for the rectangular pulse generation at the third harmonic of the Ti:Sa laser. The result is quite satisfactory. Within this program we have operated the SPARC rf-gun together with the SPARC team.

We have concluded the investigation of the spatial shaping of the laser pulse by means of the 4f-system, that is transforming the mask as special movable mirror.





As third item we have tackled the problem of the generation of a laser comb beam aiming to produce electron beam trains of THz frequency: simulated temporal pulse shape is shown in the picture.

WP 4, RF GUN AND BEAM DYNAMICS

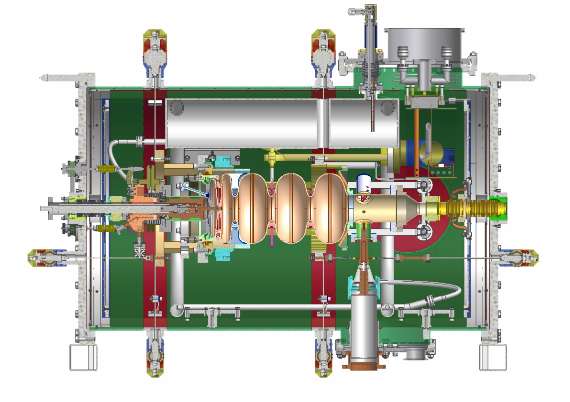
FZR

In January 2006, a new helium transfer line was installed which allow the connection of the srf gun to the ELBE helium refrigerator. The transfer line consists of a new He line from the main distribution box in the accelerator hall to cryomodule 1, a valve box above the cryomodule and an additional He line to the srf gun.

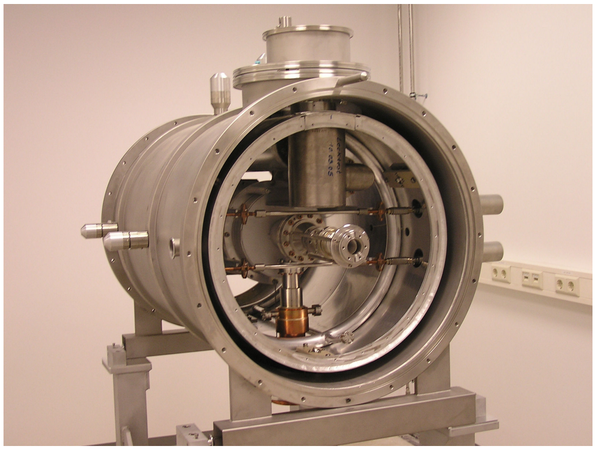
The warm tuning of the two cavities was finished and they were sent to DESY for treatment (buffered chemical polishing, backing, cleaning). The RRR300 cavity was measured in the vertical test stand at DESY two times. The results of these measurements and of warm rf measurements performed at FZR were published at the FEL 2006 conference. Unfortunately, a failure happened during high pressure rinsing. Thus the cavity had to be sent to ACCEL for mechanical treatment. At ACCEL the cavity was BCP etched and HPR cleaned. Now another rf measurement in the vertical test bench is necessary.

The assembly of the srf gun cryomodule is under way in the workshop. It includes the vacuum vessel, the liquid nitrogen thermal shield, tuning systems, rf power coupler, cathode support and cooling system and cavity support. The standard vacuum components like pumps and gauges, and the diagnostic components (temperature sensors, He level meters) have been delivered. A second photo cathode transfer system is fabricated. The tuning system was tested and measured in a test bench.

In the summer shut-down of the ELBE accelerator, the thermionic injector was reconstructed to clear the space for srf photo injector. In the driver laser room the clean room installation is finished.



Cut drawing of the SRF gun cryostat.



Assembly of the srf gun cryomodule at FZR

LAL

Status of the RF gun - The last copper pieces of the RF cells have been received just in half September instead of the end of July as it was foreseen. Yet, at this date, the two couples of end-caps (water box) have not still be received. But, fortunately it is not necessary for the RF adjustment of cells. RF measurements begun in September, 25th. We need at least one month to achieve a good adjustment of the cavities. From a point of view of the RF physics, a big step of cell dimensions occurred between the prototype and the definitive gun, one had to correct the resonant frequency by more 30 MHz. From the measurements on the definitive gun, it appeared that these corrections were reasonable for the coupler and central cavities. But, in the half cell, it seems that the "local resonant frequency" is too low. One possible way to overcome this difficulty that we are studying is to machine another cathode holder. According to the previous planning, LAL was supposed to deliver the cavities to CERN in the end of September for a brazing at the end of the year. Now, it seems the planning will be shifted by at least one month.

About the tapered waveguides, technical drawings are finished and approved by the CERN brazing specialist in early September. A selection of a tender is under way, a first quotation gives 2 weeks of machining. So, theses pieces should be fabricated by the end of the year and brazed at CERN. The last operation should take place before the brazing of the gun cells. Moreover the waveguides one brazed must come back at LAL for adjusting the RF flanges.

Vacuum pumping ports connected to the waveguides are in fabrication in the LAL workshop and should be finished also by the end of the year.

Thermal/vacuum model

Big troubles occurred during the brazing of the model. Due to some defects of the oven, there was a leak which polluted the oven preventing the brazing process during summer. Once the problem fixed, the model was brazed but the solder between the model and the waveguide did not catch and the model showed a big leak. The latter has been fixed using a UHV high temperature glue. At room temperature, vacuum tests showed a pressure limit down to 10^{-8} mbar. To reach UHV, one had to bake out and, unfortunately during the process, around 100 °C a new leak has been detected. One thinks it is probably due to the difference in thermal expansion coefficient between copper and the resin. Alternative solutions are being studied.

For the definitive brazing a “bell” has been designed to test a possible leak before the TIG soldering of the NEG envelop. The construction of this device is now under way.

Integration drawings

Drawings of the gun have been updated as shown in figure 1. Support of the gun is designed and will be machined in the LAL workshop. We had a meeting in September, 13th with E. Chevallay from CERN about the integration of the gun into the beamline. He asked the help of LAL to install the gun as it is not possible to put it directly with its girder into the tunnel because of the smallness of the chicane aperture. Moreover, CERN discovered that the gun must be pumped from two points: at the output and on the NEG chamber. E. Chevallay told us he did not know and therefore it was not foreseen. Recently, CERN people asked to us to bring several changes to the pumping system in order to reduce the need of primary pumping. It represents a new effort for LAL and can eventually lead to further delay.

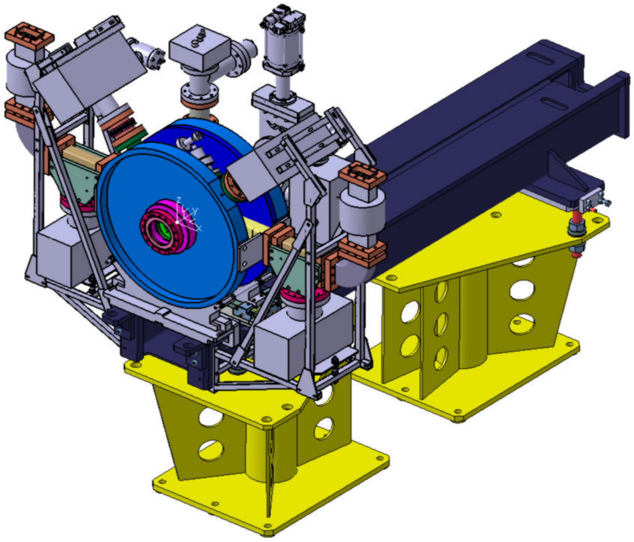


Fig. 1: 3D CATIA drawing of the gun.

Nepal station

Civil engineering begun in September, pillars are drilled into the floor (see figure2). Then, it must be left to dry for one month. After, a concrete floor is coated at the top of the pillars and again left to dry one month. Finally, walls made of concrete blocks are mounted. Before to set up the roof, all heavy elements of the machine will be installed with the crane. The end of civil engineering is foreseen for the end of January

.