# EC Contract ERBFMGECT980102

## "Development of a Combined Synchrotron Radiation and VUV Free-Electron Laser Facility"

Minutes of the 4th Project Meeting, held at Sincrotrone Trieste, Italy on the 12th March 1999.

| Participants - | |
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| Sincrotrone Trieste: | M. Marsi (MM), M. Trovò, R. Roux, R.P. Walker (RPW) + (part time) A. Abrami , B. Diviacco, A. Gambitta, F. Mazzolini, M. Svandrlik |
| CEA: | M.E. Couprie (MEC) |
| CLRC Daresbury: | A. Chesworth, J.A. Clarke (JAC), |
| Univ. Dortmund: | K. Dunkel, D. Nolle, H. Quick |
| ENEA Frascati: | G. Dattoli (GD), L. Giannessi (LG) |
| MAX-lab: | Å. Andersson, M. Eriksson, S. Werin |

### 1. PROJECT MANAGEMENT

The draft minutes of the previous Project Meeting (Daresbury, November '98) were approved, apart from a correction to the details of expenditure by CEA. Minutes of the Technical Meeting held between CLRC and Sincrotrone Trieste on the 15-16th February were distributed.

The representatives of each partner summarised the manpower and expenditure during the first 10 months of the contract. RPW presented figures for ST which indicated at least 17.5 man-months had been recorded, excluding the new recruit (M. Trovò) who had been hired to work full-time on the project from the beginning of January '99; approximately 683 kEUR had been committed. MEC showed that the CEA team consisting of herself plus D. Garzella, D. Nutarelli and L. Nahon had contributed 6.9 man-months, excluding the postDoc E. Renault, full-time since July 1st. Expenditures had been 94.1 kEUR on equipment (argon laser etc.) plus 26.2 kEUR on consumables (mirrors and substrates). JAC reported that about 15.5 man-months had been recorded for CLRC and about 260 kEUR committed. DN said that a new student is being sought at DELTA. GD said that over 5 man-months has been contributed by ENEA.

RPW reported that the result of the TMR Review held in October 1998 had been positive, and that the panel had considered that "the project is very clearly written and the scientific goals are very well set".

A brief discussion took place on the FEL'99 Conference. It was agreed to submit a non-refereed status report on the project. RPW encouraged also separate more detailed contributions for example on the optical cavity, theoretical topics etc., preferably with more than one institution involved.

### 2. TASK A: OPTICAL CAVITY

JAC reported that the design of the optical cavity was complete and that contracts had been placed for most of the equipment with the following delivery dates:

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| base blocks | March 26th |
| transfer arms | March 31st |
| X,Y,Z tables | April 23rd |
| vacuum chambers | May 7th |
| mirror mechanism | May 14th and 28th |

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| piezo system | May 15th |
| 6-axis controllers | May 21st |

Vacuum equipment has not yet been ordered. Overall costs are much higher than expected but some changes agreed with ST at the February Technical Meeting had already resulted in useful cost reductions. The possibility of ST giving further assistance is being examined. The question of recovery of VAT is being looked into. Despite some delays in placing orders, the date of June 15th for completion of all mechanical parts can be maintained. The assembly and test schedule therefore remains unchanged with expected completion on August 24th and delivery to Trieste (allowing contingency) not later than October 1st.

The problem of UHV switches had now been resolved; a normally closed type has been designed by CLRC and tests showed a reproducibility of less than 10 μm.

MM reported on experiments with In/Ga using a dummy mirror. No evidence of surface damage has been seen and the material can be removed, with some care, using ethanol. The best gap between mirror and holder seems to be about 0.1 mm and so a diameter of 40.2 mm is optimum. The depth should be 2 mm to avoid the possibility of In/Ga being transferred to the surface. MM proposed using a separate simple holder for each mirror for ease of handling and which could be easily adapted to different mirror sizes.

A. Abrami described the Unix based Beamline Control System (BCS) and its application to the control of the FEL front- and back-ends and mirror chamber vacuum equipment and coarse motors. The interfacing of the fine piezo driven motions to the BCS or to a separate PC system was discussed. MEC said that in case a feedback system is needed to stabilize the transverse position of the laser for user experiments this could probably be done with a local feedback on the electron beam position rather than the mirrors. The need for a convenient adjustment of the single mirrors from either end of the cavity was strongly stressed. It was agreed that this did not necessarily mean that it had to be done by computer, however this was considered an advantage, and could also allow other useful features such as adjustment of the optical axis requiring co-ordinated motion of two mirrors.

## 3. TASK B: MIRRORS

MEC described various improvements being made to the mirror characterisation system, including purchase of a new computer, automation of the absorption measurements, better mirrors for transport of the short wavelength Argon laser radiation. Training in making mirror measurements has been given to M. Trovò (ST) in February and M. Hirsch (Dortmund) in March. Measurements of DELTA mirrors are programmed to take place in March at 470, 420, 259, 223 and 199 nm.

MEC confirmed that sapphire substrates for ELETTRA mirrors have been ordered at a cost of 17.5 kEUR for ten of each radius (16m and 19 m), with diameter 40 ± 0.1 mm; delivery is expected in mid June. As for the coating, a visit to Mackowski (INPL, Lyon) is planned in April to discuss the situation. She said that she hoped to do degradation tests of the DELTA mirrors in the irradiation test chamber at LURE before deciding whether to proceed with Mackowski. The idea is to coat half of the substrates on the first batch. RPW stressed the need to deliver mirrors to Trieste for October 1st, even if the quality is not the best possible.

For the mounting of the mirror, MEC suggested that this is done under a laminar flow hood.

MM said that in parallel with the development of multilayer mirrors on transparent substrates, ST is investigating the possibility of using silica or metallic substrates for removing power problems, combined with hole output coupling.

## 4. TASK E: THEORY

GD reaffirmed the statement made at the last meeting that if FEL saturation is induced by increased bunch length and energy spread the power output is limited to about 1 W. If however the bunch length does not increase the power could be up to 3 W. He then reported on some studies that had been carried out at ENEA regarding the use of APPLE-2 type undulators in FELs. Some small changes are introduced in the gain and saturation intensity but are not very significant. More interesting is the situation of opposite polarization in the two undulators. With exact circular polarization the radiation generated should have linear polarization but the interference term due to the modulator is removed and so the modulator gives no gain enhancement. The question of what happens at saturation is still be studied.

LG reported on his studies of gain optimization and use of hole output coupling. He said that he had considered use of elliptical mirrors to optimize the gain but since the optical mode size is always larger than the electron beam the effect is not very large. At the stability limit a maximum gain of 69 % is obtained, compared to 34 % for the nominal situation in the non-optical klystron mode. Calculations of the effect of holes had been carried out involving the summation of the first 3 TEM modes, the minimum set required to allow a solution with zero intensity at the hole centre. Considering for simplicity a symmetric cavity with 4 m Rayleigh length, a 1 mm hole radius should give only 1 % output coupling. The gain in this situation should not be much different since the electric field distribution in the undulator is not changed very much by the presence of the hole. Further studies are planned.

## 5. TASK D: ELECTRON-BEAM TESTS

M. Svandrlik summarised the method being used in ELETTRA to compensate the effect of higher order mode impedances introduced by the r.f. cavities. Spectrum analyser measurements indicate that a stability of all 4 coupled bunch modes at less than $0.3^{o}$ of phase motion (1.7 ps) had been achieved. RPW reported on the status of the streak camera, which is now operating in the double-sweep mode. The camera will be used during the two shifts dedicated to bunch length and stability measurements in the FEL mode programmed for the following two days ($13^{th}$ and $14^{th}$ March).

## 6. TASK C: UNDULATOR AND FRONT-END

B. Diviacco presented the final layout and status of the optical klystron. A shorter vacuum chamber had been chosen compared to that indicated previously (4659 mm) for compatibility with other straight sections and to allow the future possibility for implementing new high accuracy BPMs that are under development. Nevertheless the fringe fields with the closer magnet spacing are still acceptably low and should not cause any problems. He described also the improvement made to the design of the permanent magnet block holders in order to permit both horizontal and vertical movements for field correction; delivery of the holders is expected in June. The blocks themselves are expected in April, and the carriages in May and June. The design of the electromagnetic modulator has been finalised and orders placed for the magnet and power supply construction, with delivery in July. The programme now shows one undulator being ready in August, the second in September.

B. Diviacco also presented the results of an accurate calculation of the power emitted by the undulators, using calculated magnetic field distributions rather than an analytic formula. At 1 GeV, 100 mA, 350 nm, the central power density is 0.4 W/mrad$^2$ and the integrated power on 35 mm diameter is 1.8 W. The power emitted by the modulator has also been calculated; at the nominal maximum Nd=80, corresponding to a peak field of 0.8 T, the power density is 0.5 W/mrad$^2$ and the integrated power is 0.9 W.

F. Mazzolini described the layout of the front-end and back-end and the respective mechanical and vacuum components. A. Gambitta presented the design of the new aluminium vacuum chambers and in particular the modifications required to increase the vertical slot height from 10 mm to 20 mm in the upstream and downstream bending magnet chambers.

## 7. TASK F: FEL COMMISIONING

The diagnostics required for FEL commissioning were discussed. HQ, DN and MEC described the tools available at DELTA and LURE respectively and in particular the characteristics of their monochromators. It was agreed that it must be capable of resolving also the laser linewidth, not only the spontaneous radiation, and also that a CCD line for a 'live' picture of the spectrum, with lower resolution, is very useful for setting up.

MM presented the layout of the front- and back-end radiation and laser hutches. It was pointed out that it would be much better to extract the light from the front-end hutch rather than use a CCD camera for remote viewing. MM said that this would be done by deflecting the FEL radiation through 3º using a mirror that would be situated in the "switching mirror chamber" that is being built for the SR beamline. The FEL beamline will then terminate shortly after emerging from the radiation hutch at a valve followed by a window. From there the FEL radiation will be transmitted in air to a diagnostic area which will contain the monochromator as well as alignment equipment. At the back-end the idea (at least in a first phase) is to extract the FEL radiation through a window at the exit of the mirror chamber, and then to transport it into the existing SR diagnostic area where the streak camera is located, and into which the FEL alignment and diagnostics will be integrated.

## 8. CONCLUSION

RPW proposed that the next meeting is held at Daresbury to give the opportunity to see progress with the construction of the mirror chambers, at a date to be agreed in late June or early July.

## SUMMARY OF MAIN ACTIONS:

- investigate possibility of individual mirror holders (CLRC)
- decide on supplier for mirror coating (CEA)
- complete design of radiation and laser hutches, including safety aspects (ST)
- investigate availability and suitability of excimer lasers for mirror measurement (CEA)
- calculate photo-desorption in mirror chambers (CLRC, ST)
- set up web site (ST)

R.P. Walker
Trieste, 30th June, 1999