

EC Contract ERBFMGECT980102

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

Minutes of the 5th Project Meeting, held at Daresbury Laboratory, England
on the 28th June 1999.

Participants -

Sincrotrone Trieste:	M. Marsi (MM), R. Roux (RR), R.P. Walker (RPW)
CLRC Daresbury:	N. Bliss (NB), A. Chesworth, J.A. Clarke, C. Hill, M.W. Poole (MWP)
Univ. Dortmund:	H. Quick (HQ)
ENEA Frascati:	L. Giannessi (LG)

1. PROJECT MANAGEMENT

The draft minutes of the previous Project Meeting (Trieste, March '99) were approved with some minor corrections that will be included in the final version.

MWP presented CLRC's Cost Statement for the Annual Report. RPW said that once a final version has been received from ENEA, it would be sent as soon as possible to the EC.

RPW suggested that the possibility of obtaining a refund for VAT in accordance with article 3.2 of the Contract should be looked into. There followed a discussion on possible VAT payment on goods shipped from CLRC to ST. It was agreed that CLRC would remain owners of this equipment, and that it should be sent on long-term loan. The mechanism for doing this needs to be investigated.

RPW said that all suggested alterations to the Annual Report received from CEA, CLRC, Dortmund and ENEA would be included in the final version. After discussion it was agreed that a modification would be made to the description of the second year's activities to allow further margin in the initial commissioning period.

On the question of manpower and costs, RPW said that in the first year ST had recorded 28.5 man-months (34% of the predicted total) and had committed 853 kEUR; he added that a number of large orders were in the pipeline and that over 1000 kEUR will have been committed by the end of June. MWP said that the effort recorded up to the end of April was 22 man-months (103 % of the predicted total) and that 290 kEUR had been committed up to date.

RPW announced that a project web site has now been set up (<http://www.elettra.trieste.it/sites/euprojects/fel/>) and thanked MM for doing this. He asked for any comments or suggestions to be addressed to himself or MM. It was agreed to distribute minutes and internal notes by this means, with suitable password protection.

Regarding the FEL99 Conference, 3 papers connected with the Project have been accepted for poster presentation on general status (RR et al.), the optical cavity (MWP et al.) and on FEL operation with a helical optical klystron with opposite polarization (G. Dattoli et al.). The first will be submitted as a non-refereed status report and the others as full length articles.

2. TASK A: OPTICAL CAVITY

MWP reported on the general status of the of the mirror chamber construction. The majority of components have now been delivered. The windows have not yet been ordered but are on short delivery nor the special adapters to allow them to be mounted at an angle with respect to the beam path, which could be constructed in-house. In addition only one mirror holder has been ordered so far; the remaining ones (6 in total) will be ordered

following assembly tests, allowing therefore the possibility for small modifications to be made. MWP requested that the RGA's ordered by ST should be delivered to Daresbury.

Vacuum conditioning and assembly in the clean-room began in early June, in agreement with the programme. The programme now shows completion of assembly of both systems on September 20th and delivery to Trieste on the 28-30th. The previous 1 month contingency has therefore been used up in making a more detailed and realistic assembly and test schedule, taking into account also the limited resources that must also be used for other projects.

NB reported on the results of tests of the XYZ table and mirror mechanism motor drive systems. The XYZ tables have been tested both at the factory and at Daresbury. The maximum error observed was 7 μm , however for the most part the accuracy and repeatability were within 3 μm , close to the specified $\pm 2 \mu\text{m}$. The pitch and yaw errors were small ($\approx 30 \mu\text{rad}$) over the full motion range ($\pm 5 \text{ mm}$). The mirror change motion showed good reproducibility ($< 5 \mu\text{m}$ at the mirror positions) but larger absolute errors; NB pointed out however that the latter is not relevant since the uncertainty in the mirror position is determined by the mirror holder. Provisional tests have also been carried out on the mirror mechanism coarse pitch and yaw motion, before UHV cleaning. The main error is due to backlash (up to 100 μrad in one case), the remaining accuracy and repeatability being within specification.

The mechanisms will be now stripped down, UHV cleaned, re-assembled with the UHV motors and piezo translators before assembling in the vacuum chambers, after which all motions will be tested with the motor control system (Assy. A: 15-19 Jul., Assy. B: 6-10 Aug.). Further assembly and survey work will be carried out before the system is leak tested and baked (Assy. A: 18-27 Aug., Assy. B: 9-20 Sep.).

A decision has yet to be taken on the type of packaging and the degree of stripping down that will be made before delivery. At the moment a single delivery is planned.

MPW confirmed that CLRC will supply flow meters. The need for flow switches was discussed and it was agreed that this was necessary to avoid possible damage. MWP agreed that CLRC will cover the cost of the extra switches. NB agreed to supply the necessary details to determine compatibility with the ELETTRA BCS.

The type of window material was discussed. It was agreed that 38 mm diameter is sufficient and that MgF_2 is the most suitable for transmission to short wavelength, but there was some concern over its weaker strength with respect to sapphire. HQ said that DELTA uses MgF_2 , but in that case the radiation is first reflected through 45° in order to remove the high energy radiation. After discussion it was concluded that for spontaneous emission tests the power could be reduced if necessary using the double slits. HQ agreed to pass on any information available on MgF_2 at Dortmund. NB agreed to try to obtain information from the suppliers, including cleaning and bake-out requirements. It was agreed to purchase 3 windows (2 + 1 spare) and to construct 2 angled adapters. RPW agreed to purchase the windows, one of which will not be mounted on the mirror chamber but after the switching mirror, while MWP agreed to supply the adapters.

NB confirmed that the nominal length of the chamber is 502 mm ($\pm 1 \text{ mm}$) between input and output flanges, as shown on the latest drawings. NB proposed a support for the transfer arm to prevent damage to the mirror chamber if it is knocked. It was agreed that this is a good idea provided that the support is easily removable since access is required under the arm.

3. TASK B: MIRRORS

MM reported on information supplied by M.E. Couprie on the irradiation and measurement of one of the DELTA 259 nm $\text{Al}_2\text{O}_3/\text{SiO}_2$ mirrors, coated by IOF, Jena on a sapphire substrate (from Kyburz, Switzerland). After 113 mA-h of irradiation with the

spontaneous emission of the SuperACO FEL undulator the absorption had increased from 0.13% to a probable value of 4.7%, confirming the greater sensitivity of mirrors made by electron beam deposition to radiation damage. The stated conclusion was that EBD mirrors are not a good solution for the front mirror in ELETTRA. RPW however questioned this statement in view of the much lower power density in the case of a helical undulator, and suggested that in the absence of any real alternative at present a test on ELETTRA should nevertheless be considered.

MM also presented a communication from E. Renault and D. Nutarelli on a meeting with a representative of RSA le Rubis, to which has been ordered the substrates for the ELETTRA mirrors, according to which RSA is no longer able to supply the required substrates on time and with the original cost because of the need to change tooling. The only possibility to obtain mirrors in September appears to be to accept a common radius of curvature (17 m) and significantly lower quality. RPW indicated his displeasure that this should be announced now, given the amount of time that has elapsed since the order was placed (and that the delivery was expected in mid June) and there was general concern that this could delay the initial commissioning. It was agreed to try to bring pressure on the company to make a better offer, and that meanwhile alternative suppliers would be also be contacted.

MM reported also on the parallel activity initiated at ST to use silicon substrates with either Al or multilayer coating and hole output coupling. An order has now been placed with SESO (25.8 KEUR) for 10 substrates of each radius (16 m and 19 m), half of which will be coated with UV enhanced Al. Various hole sizes will be made, which have yet to be defined.

4. TASK C: UNDULATOR AND FRONT-END

RPW described the up-to-date layout showing the recently defined front and back radiation hutches and diagnostic hutches, orders for which are in the process of being made.

Regarding the undulator, all components have been received for the first section and construction has begun. A short 6-period section, complete with terminations, has recently been completed and will soon be measured to check that there are no significant magnetic errors, in view of the fact that there were various uncertainties and omissions in the magnetic measurements of the blocks supplied by Sumitomo. The second carriage is nearing completion at EOTECH and due for delivery in early August. The modulator (SigmaPhi) and power supply (OCEM) are due for delivery by the end of July. Installation of one section is foreseen in the August shutdown (Aug. 2-22) followed by the second section and modulator in September (Sep. 20-29).

The vacuum chambers are all progressing according to schedule. The ID chamber has been delivered and is under conditioning and test in the vacuum laboratory. The downstream bending magnet chamber is mechanically complete and will be vacuum tested in the factory next week. Installation of both vessels, complete with pumping chambers, and beam shutter etc. is programmed for the August shutdown. The design of the upstream bending magnet vessel is complete and construction is proceeding toward delivery at the end of July and installation in September.

The front-end is being assembled in-house using a modified frame and the main components (mask, stopper, delay line, double slits) are due for delivery in the near future. Installation of the radiation hutch is programmed for the end of July followed by the front-end in August. The order for the back-end beam line has also been placed (delivery end August) ready for installation in September.

5. TASK D: ELECTRON-BEAM TESTS

RR summarised the results of bunch length measurements made in 4-bunch mode at 1 GeV following the last Project Meeting, as well as subsequent measurements in single bunch at 1 and 2 GeV. Good agreement was obtained between single shot and averaged data indicating an absence of instabilities, as confirmed by frequency domain measurements which indicated $< 0.2^\circ$ amplitude of phase motion. Data taken on March 13th and 14th were in excellent agreement. The profiles are symmetric, but with some discrepancy between the rms and FWHM/2.35 values. The peak current, calculated from the ratio of peak to average value, reaches 200 A at 20 mA/bunch and 250 A at 27 mA/bunch. Later single bunch measurements were in very good agreement below 15 mA/bunch; above this there is a discrepancy of about 2 ps which is not understood. 2 GeV data are in good agreement with 1 GeV as expected when above the microwave instability threshold.

6. TASK E: THEORY

LG presented his recent studies of hole output coupling. The previous model used a superposition of the first 2 Laguerre modes having zero electric field at the hole centre. A later model with 3 modes, setting also the second radial derivative of the electric field to zero, showed diverging behaviour with significantly lower losses and higher electric field in the undulator. A more general approach has therefore been developed in which the electric field configuration in the cavity is defined by the eigenvector of the round trip operator with the highest gain (i.e. lowest losses). Such a model confirms that the more modes are included, the lower the losses. However, it has also been found that smaller mirrors can result in increased output coupling, since the mirror size determines the number of modes. The effect of the FEL interaction has also been included in the same approach. An interesting result is that without any hole, the FEL mechanism alters the mode distribution, and can result in larger gain at a different detuning. The gain function is also wider than the nominal $1/2N$ which might indicate less sensitivity to energy spread. One practical result that includes 23 % round trip losses (88 % reflectivity per mirror), 20 mm mirror radius and 1mm hole radius, indicates a net gain of 1.7 % and output coupling of 0.45 %. The strong influence of mirror size is shown by a result with 5 mm mirror radius which gives a gain of 7 % and coupling of 1 %. Further calculations have to be carried out to test convergence with respect to the number of modes and accuracy of calculation before definitive predictions can be made.

7. TASK F: FEL COMMISSIONING

RR described the characteristics of the 160 nm–visible monochromator that has recently been ordered by ST for spontaneous radiation and laser diagnostics that will be carried out in the front-end laser hutch. With the 1200 lines/mm grating a single shot acquisition covers 41 nm with 1.2 Å resolution sufficient for measurement of the spontaneous spectrum. Measurements to be made will include undulator and modulator calibration, axis determination and energy spread measurement. With the 3600 l/mm grating the resolution of 0.4 Å should be sufficient for the laser line. Other equipment in the process of being ordered include optical tables and components, photomultiplier, and two PCs for the front and back ends.

RR also described the proposed ‘self collimating’ alignment procedure to align the plane back-face of each mirror to the direction of spontaneous radiation. A discussion took place on the relative merits of this procedure compared to an alternative method based on reflection from the front surface. It was concluded that a more detailed assessment should be carried

out, looking also at the sensitivity and range of correction etc., and a written proposal made which can be circulated between all partners.

8. CONCLUSION

It was agreed that a meeting should be held during the FEL'99 Conference at a time and place to be arranged.

SUMMARY OF MAIN ACTIONS:

- investigate possibility of VAT recovery and means of shipment of goods from Daresbury to Trieste (CLRC, ST)
- set up password protected area on the web site for distribution of minutes etc. (ST)
- arrange delivery of RGAs to Daresbury (ST)
- supply details of flow switches and arrange purchase (CLRC)
- obtain information on MgF_2 properties, and UHV treatment (CLRC, Dortmund)
- purchase windows (ST) and construct adapters (CLRC)
- continue output coupling calculations (ENEA)
- prepare optical cavity alignment strategy (ST)

R.P. Walker
Trieste, 2nd July, 1999