EC Contract ERBFMGECT980102

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

Notes of a Technical Meeting, held at LURE, Orsay, October 6-7th, 1998

Present: Sincrotrone Trieste: Alessandro Gambitta, Marino Marsi
CEA: Daniele Nutarelli, Eric Renault
CLRC Daresbury: Neil Bliss, Andrew A. Chesworth, Barry D. Fell
Univ. Dortmund: Henrich Quick

1. GENERAL DISCUSSION: STATUS OF THE PROJECT

Since some of the people attending this meeting were not present at the meeting in Virginia (August 19th, 1998), M. Marsi explains briefly the general layout of the optical cavity; in particular, the decided values are presented for positions of front and back mirrors (14.7 and 17.7 m), effective aperture of the cavity (3.2 mrad), position and size of front-end radiation mask, double slits, slots of storage ring vacuum chamber. The possibility of using two identical UHV vessels for front and back mirrors is also confirmed. N. Bliss asks for an up-to-date version of the front end drawings, where such details are clear. (by regular mail, or ftp).

2. MIRROR SIZE

Looking at the values provided by R.P. Walker on the angular distribution of the undulator synchrotron radiation (SR) power, N. Bliss and B. Fell point out that having large mirrors is a disadvantage from the point of view of the radiation power, and raise the question of how much SR should be allowed to impinge onto the mirror, i.e. what should be the mirror radius. M. Marsi says that a reasonable estimate for the maximum allowed SR power would be to stay below the absorbed FEL power, which can be estimated to be between 1 and 10 W. B. Fell points out that in the FEA calculations he prepared for the meeting he did not take into account the FEL power (also because nobody told him to do so). M. Marsi also says that at this stage, as far as design of the holders/manipulator goes, it appears reasonable to assume a mirror diameter of 40 mm: if a reduction of the incident power is needed, this can be done by changing the radius of an annulus shaped shield covering the outermost part of the mirror, which is also where the thermal contact with the holder takes place, as it will be discussed later in more detail (see below).

The thickness of the mirrors is also considered. In order to have the mirror surface in the pivoting point of the manipulator, N. Bliss points out that the mirror thickness has to be known precisely before constructing the mirror holders and that, if flexibility in thickness is required, an assembly using spacers (replaceable, of different thickness) should be used. M. Marsi says that 4 mm thickness should be assumed, and that the idea of using spacers should for the moment not be considered; it is also pointed out that, in case, being 1 mm away from the pivoting point should not be too much of a problem for the rotations.

3. GENERAL PRESENTATION OF MIRROR VESSEL AND MANIPULATOR

After this general discussion, N. Bliss shows the latest version of the mirror chamber drawings, with associated tolerances and ranges for the various movements (see attached Table, Annex 1). In particular, 40 mR are possible for coarse pitch and yaw motions (changed from the values presented at the last meeting).

4. THERMAL LOAD - GENERAL

To correctly discuss thermal load issues, B. Fell asks then what would be the acceptable roughness (on the local, atomic scale) and/or slope errors (non homogeneity of radius of curvature) on the mirrors. D. Nutarelli says that for the SuperACO mirrors, a roughness of less than 1.5 Å is required, and that the manufacturers are asked to provide slope errors better than $\lambda/4$ over the whole mirror (where λ is the He-Ne laser wavelength, ~600 nm).

5. MIRROR HOLDER

The mirror holder issue is then discussed, and the relative merits of two possible approaches:

A) “old” SuperACO design, with contact on the front of the mirror guaranteed by three screws
B) “new” SuperACO design, with two semi-circles clamping the mirror on the side.

As it is will be discussed later during the presentation of the FEA calculations, it was pointed out that (B) provides better thermal contact but, given also the different extension coefficient of copper and silica and/or sapphire, it will cause distortion problems. D. Nutarelli confirms, based also on the direct experience of the CEA group. Design (A) gave very poor thermal dispersion. When (B) was adopted, at first the mirrors were mounted tightly, and only a slight increase in temperature (20 C) was measured on the mirrors during FEL operation, using the “in situ” interferometric temperature measurement method at SuperACO; unfortunately, this caused severe distortion of the geometrical profile of the mirror surface (compromising the possibility of lasing). The SuperACO group empirically learned to adjust the tightness of the screws to obtain an intermediate situation.

M. Marsi says that the mirror holder problem is certainly a very delicate one, but that the design of the UHV vessels and of the manipulator (i.e. the rototranslation mechanism, which are at the moment the most urgent issues) can go on without requiring detailed decisions on the holder. The problem should be studied and some tests should be done for possible solutions (he asked the CEA group when it would be possible for them to coordinate such tests at SuperACO, using for instance their conventional laser to simulate the SR heat load).

B. Fell presents the results of his FEA calculations, distributing also his detailed report. He shows that assuming 4 Watts on the mirror (corresponding to 1 GeV, 200 nm, K=3.784, 40 mm mirror diameter in the tables provided by R.P. Walker), the temperature of a mirror at thermal equilibrium given only by irradiation would exceed 230 C. Everybody agrees this is not acceptable, because such a temperature would destroy the multilayers, which are the active part of the mirrors. Also taking into account the fact that the FEL heat load was not considered, and that this might well be estimated to be 4 Watts, independently of the mirror diameter, everybody agrees that effective cooling is required. At this purpose, three problems should be considered:

(i) good contact between mirror and mirror holder
(ii) good contact between mirror holder and copper base plate
(iii) water cooling of the copper base plate

For (i), a sample holder as depicted in Annex 2 is considered. The mirror would fit loosely in the holder, and a good thermal contact would be guaranteed by InGa or some kind of UHV “grease”, anyhow something liquid which guarantees thermal contact and avoids the problems due to the different expansion of sapphire and copper (i.e., distortion of the geometrical profile of the mirror). Some springs would gently press on few points of the mirror surface, to guarantee stability and without reducing the useful area of the mirror.
For (ii) good machining and good springs in the proposed design are requested.
For (iii), everybody agrees it is necessary to keep the copper base plate as cold as possible.

Assuming these solutions, and assuming that the copper base plate stays at 20 C thanks to water cooling, a +14 C gradient between base plate and mirror holder would be predicted (34 C on holder), and a +2 C gradient between holder and mirror (36 C on mirror). This would be a desirable case, to protect the multilayers and to avoid geometrical distortion of the mirror surface.

A. Gambitta shows also the results of his calculations; even if not as detailed as Fell’s, the results are in qualitative agreement, and the same problems and possible solutions are pointed out.

D. Nutarelli shows “real life” mirror holders corresponding to the (B) design, and a new one (C) which resembles the one in the sketch by CLRC. The main difference between (C) and the one proposed by CLRC (Annex 2) is that the tolerance between mirror and holder is much larger (~2 mm), so that no contact using InGa on the side of the mirror is possible (rather, the contact would take place on the “base annulus”), and that three rather than four springs are used. It should be tested soon on a “test” substrate and a conventional laser.

D. Nutarelli points out the fact that extreme care should be used to avoid ruining the active surface of the mirror with the InGa; also, some of the InGa remaining on the silica/sapphire after use and mechanical cleaning with alcohol might cause this kind of problem during the regeneration procedure which involves heating up the mirror to 250 C in low vacuum.
M. Marsi says that Ga is known to attack Al, so that its effects on sapphire should be also tested. N.Bliss says that at DL they should have a recipe to clean InGa (they used it). A. Gambitta points out that only In can be used between mirror base and holder. Everybody agrees tests are needed.

6. SHIELD

The problem is then discussed of a shield, to protect the outermost part of the mirrors and the mirror holders from the SR power. In this way, the mirror would receive only the FEL power and the SR power amount corresponding to the size of the hole (which will be possible to be changed easily); the outermost border of the mirror (which is where the contact with the rest of the world takes place) and the mirror holder would not receive any radiation power directly. Mirrors of 40 mm diameter considered as a reasonable choice.

Two solutions are proposed:

a) a shield solidal with the mirrors. In particular, a shield in thermal contact with the Cu base plate and covering it all, at a certain distance from the mirrors and with three holes (one for each mirror) slightly smaller than the mirror diameter. This would be efficient, because it would benefit of same water cooling system acting on the Cu base plate, cheap, easy to be changed and/or modified. Problem: it might make the mirror exchange operation more cumbersome.

b) a shield mounted separately from the mirror holder system, shaped as a circular hole with the following feature: independent mechanism synchronized with the mirrors, to follow them in their adjustments; independent water cooling; possibly positioned in a separate UHV vessel. Inserting such a system before the mirror holder would be expensive and complicated; but since all these requirements correspond to the "double slit" of the front end, it was agreed that the possibility of synchronizing its movement with the mirrors should be explored. The disadvantage is that the double slit is a square hole, so it cannot effectively screen a circular mirror.

It was agreed that (a) and (b) are worth being explored in parallel. N. Bliss says he will try to fit in the design of the base plate such a shield, if so will permit the time and budget constraints they are facing at this point. The ELETTRA group will explore (b). Of course, the simultaneous use of both (a) and (b) would represent the optimal solution.

7. UHV MIRROR CHAMBERS

N. Bliss asks for a more detailed layout showing where all the electronics racks will be with respect to the mirror chambers, to be able to decide the cable lengths and other similar issues. He also asks what interfacing protocol is normally used at ELETTRA, for gauges and motors. M. Marsi and A. Gambitta say they will ask A. Abrami about this.

N. Bliss presents a study by the vacuum group of CLRC on the mirror chambers. In particular, he points out that the limit switches which are being considered right now would be fairly bad for the vacuum, both in terms of degassing and especially in terms of hydrocarbon content. He invites everybody to suggest possible solutions for alternative UHV compatible, small size, high precision limit switches. The question was raised of what precision is needed: apparently, only in case of power failure they would be really needed, because they should be used as reference point for the motors. M. Marsi will provide information on the ones used at ELETTRA.

The mirror introduction systems is then discussed. M. Marsi will provide an alternative design, used at ELETTRA, which would permit one more degree of freedom (rotation of the arm) and could be useful during the transfer procedure. In this way, the CLRC group will be able to compare it to the commercial VG one they plan to adopt. It was recommended that the introduction chamber should "slide" on its support to facilitate thermal expansion during bakeout.

Windows and vacuum ports of the mirror chambers are then analyzed in detail. The addition of a few of them is suggested, to facilitate transfer, to permit in situ interferometric temperature measurements, etc. The big bottom flange is suggested to be removed, which requires some work and some care because it should be ascertained that the screws connecting the mechanism to the external shaft are accessible from the top. N. Bliss takes note of all suggestions, and will explore their feasibility.

8. SCHEDULE

Even though some delays start to accumulate with respect to the original time table, it was agreed that the original deadlines should be kept as tentative goals. N. Bliss says that before the end of October, CLRC will try to start the bidding procedures (the manipulator mechanism is regarded as the most urgent component). As soon as the tentative “final” design of the various parts is done, it will be sent to R.P. Walker (ftp, for instance) who will circulate among the partners for comments and hopefully final approval (as soon as possible).

SUMMARY OF MAIN TECHNICAL CHOICES

• For manipulator design purposes, mirrors of 40 mm diameter, 4 mm thickness assumed
• Water cooling needed
• InGa or similar needed between mirror and holder. “Clamping” holder not recommended
• Shield needed (explore both “solidal” or “remote” solution)
• flanges and pumping on UHV vessels approved, with some minor improvements

SUMMARY OF MAIN ACTIONS

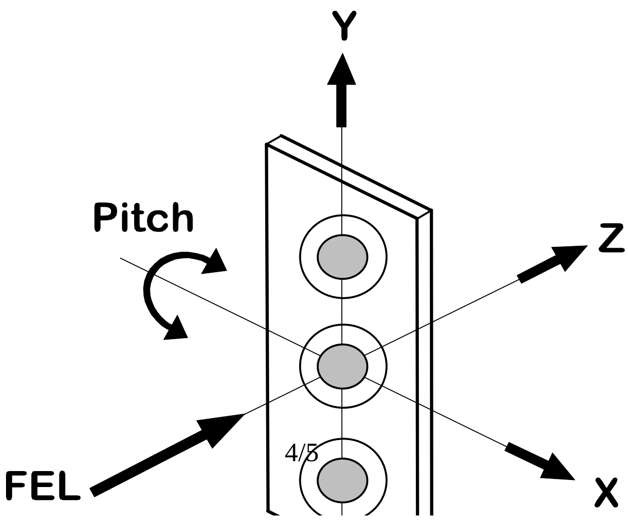
• Modifications of UHV vessels, adding shield, if possible (CLRC)
• Provide info on limit switches, UHV glues, transfer arm, interfacing, general layout (ST)
• Explore possibility of using double slit as shield, synchronized with manipulator (ST)
• Tests on mirrors/holders should be planned. At the moment not as urgent as the other issues, but it should be started (ALL, coordinated by CEA)

M. Marsi, Trieste, October 12th, 1998

Annex 1.

Table of motions for both front and back mirrors

Motion	Resolution	Accuracy	Repeatability	Range	Drive	Control
X_1	0.5 μm	2 μm	2 μm	±5 mm	external motor	open loop
Y_1	0.625 μm	2 μm	2 μm	±5 mm	external motor	open loop
Z_1	0.5 μm	2 μm	2 μm	±5 mm	external motor	open loop
Y_2	1.25 μm	5 μm	5 μm	190 mm	UHV motor	open loop
Pitch fine	0.009 μR	0.1 μR	0.1 μR	136 μR	UHV piezo	closed loop
Pitch coarse	11.4 μR	57 μR	57 μR	40 mR	UHV motor	open loop
Yaw fine	0.009 μR	0.1 μR	0.1 μR	136 μR	UHV piezo	closed loop
Yaw coarse	11.4 μR	57 μR	57 μR	40 mR	UHV motor	open loop
X_3	0.25 mm	0.5 mm	0.5 mm	±10 mm	manual	
Y_3	0.25 mm	0.5 mm	0.5 mm	±15 mm	manual	
Z_3	0.25 mm	0.5 mm	0.5 mm	±10 mm	manual	



Annex 2.