CRYO-READY UNDULATOR U15: PASSING SOLEIL'S 2 METER THRESHOLD IN USEFUL MAGNETIC LENGTH

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Abstract

The U15 is an in-vacuumundulator designed to operate at room temperature and at 70K. It is the first in-vacuum undulator designed, assembled and which will be used in SOLEIL's storage ring that have support beams for magnets longer than 2 meters.A clear gap is felt in the technologies used for manufacturing and assembling compared to our standard 2m length in-vacuum undulators. This is due, in part, to the tolerances imposed by the maximum phase error admissible in SOLEIL's storage ring. The poster will shine lights on those difficulties from a design and manufacturing point of view.

INTRODUCTION

The SOLEIL Synchrotron is in operation since May 2006. 18 of its beamlines use undulators as sources. The first undulators were electromagnet-built (such as HU 640[1]) and Apple-IIs followed since a few years by in-vaccum (cryogenic or not) undulators.

The U15 undulator will be first used in the frame of the LUNEX5 (free electron Laser Using a New accelerator for the Exploitation of X-ray radiation of 5th generation) project of advanced and compact Free Electron Laser (FEL). It will be used for a test experiment of FEL with a laser wakefield accelerator under preparation in the frame of the COXINEL ERC Advanced Grant project[2]. It has been designed as the longest possible magnetic field that can be used for this experiment: 3 meters.

In the design and building phases of the U15, there was a clear threshold that complicated nearly every step of the project compared to the U18s even if the basis of both instruments are very close to one another.

CONTEXT

The in-vaccum in used at the moment are U20s, functioning at room temperature and one cryogenic U18 (a second one is being built). Both are two meters long (with a magnetic period of 20 and 18 mm respectively). The Apple-IIs are typically 2m long when electromagnet-based undulator can reach 6 meters. In the past, HU640 was so long and heavy, that it has been partially reassembled directly in SOLEIL storage ring. This process is not compatible with in-vaccumundulators considering the level of cleanliness required for a storage ring.

The phase error disturbs the electron dynamics in the storage ring, and causes a reduction in the intensity of synchrotronradiation in an undulator as well as impacting the lifetime of the electron beam. In a facility of SOLEIL's size, the beam is very sensitive to the phase error compared to larger storage rings. The definition of the magnetic fields in each undulator (as well as any potentially magnetic instrument affecting the beam) is critical in its impact on the electron beamline.

CHARACTERISTICS OF THE UNDULATOR

- The magnetic useful length of the undulator being 3 meters, its overall length has been designed as 3,4 meters. Its height (2,2m) and depth (1,52m) are closer to U18s and U20s

- It is designed to functions both at room temperature and 70K. The compatibility for both temperatures is a difficulty in itself: the difference in temperature between max and min imply a 12mm shortening of the in-vacuum beams.

- The magnetic forces between the beams are of 10 tonnesfor a 2,6mm gap. The undulator will serve to test the effects of tapering on the electron beam.

PRE-DESIGN AND BUDGETING PHASE

The study of the buildings where the undulator will transit and will be assembled before starting the design is crucial. The most significative element that can be examined beforehand is the assembly of the vessel: adding 1meter to the magnetic length of the undulator adds 2meter at the minimum to the length needed during this stage.

Study of the existing assembly process is then a point to investigate. The beams supporting the magnets are made of aluminium in our IVUs and are light enough to be handled by hand by only two persons. Investigating the efforts needed during manutention and calculating the impacts of adding 50% of length shows that the handling is not possible at all without lifting tools.Are those lifting tools available near the assembly space? Are those lifting tools as long as needed for the new design?

When investigating this second point for example, we saw that our tools and buildings restrained the positions possible for the assembly process to only two options. One of theserequiresto move and recalibrate several instruments in the assembly hall. These questions have several effects on the final budget and the manpower needed for the project and may impact the decision of starting the design or greatly change the time table of the project.

Finally, it is important to study the industrial partners of the lab. When changing one parameter, you can eliminate an experiencedpartner and have to rely only on companies more expensive than first expected. The Western-European industrial network seems to be separated between the companies that use mills and turning mills up to 2.5mx2.5m milling capacity and the companies that use machines with a capacity of 6m to 12m. It is difficult to find companies in between and to evaluate their level of expertise if you do not already work with them.

The second parameter that separate these companies are the markets which they target. Bigger capacities companies often work for big budget clients and are not interested in the risks they would have to take to comply with our demands. Those that do understand our needs, usually work in the nuclear field of expertise and have very high structural costs.

These two parameters hugely impact the budget. The next table will show our experience. The price for 50% longer beams is not 50% higher. This one example can be used several times in the design portion of the project.

DESIGN PHASE

Augmenting the length DOES NOT augments linearly other parameters. We decided early in the pre designing phase to not take anything for granted even if the base of the U18s and U20s is strong and efficient.

Firstly, more precision is needed to keep a low phase error on a longer distance which demanded a new module designand more a controlled assembly process. The final characteristics needed for the U15 brought us into the micro-mechanic field. When it was possible to differentiate the standard modules and the modules that would fix sensors and probes on a 2m beam, it is no longer the case for a longer beam that cannot be machined as precisely, and thus, that needs more precisely tuned modules on the entirety of the useful magnetic length.

The second point is that assembling 200 modules is way more than twice easier than assembling 400. Even with a final precision being the same in both cases. Labs are rarely equipped for chain work and the precision of assembly will decline during the time needed to assemble all modules without the help of tools during the whole process.

Lastly, as seen before, tools and process are to be rethought (or reevaluated) when the proper design is at an advanced stage. Longer beams augment the maximum deformation even with the same value of linear efforts. For instance, the tool used to attach the two magnetic beams together for the assembly in the vessel had to be redesigned to avoid contact between the two rows of magnets.

REFERENCES

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Table 1: Relative Prices For Similar Beams

Company	**2m beams** (mean price for 2 projects – 2014 and 2015)	**3m beams** (Price for 1 project – 2016)
1	98	154
2	52	Machine capacity to small
3	100	195
base 100 for the highest price offered in 2015		