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W164: A WIGGLER DEDICATED TO THE PUMA BEAMLINE AND THE FEMTOSLICING PROJECT AT SOLEIL

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Abstract

An out-vacuum wiggler, W164, was designed, built and installed on the SOLEIL storage ring with the double objective to produce high energy photons for the PUMA beamline (10 keV to 70 keV) and to be used as a modulator for the FEMTOSLICING project [1]. The insertion device requires simultaneously reaching high critical energy of photons (above 10 keV) and low resonant energy (1.55 eV). The wiggler is composed of 20 periods of 164.4 mm made of NdFeB magnets and Vanadium Permendur poles. The maximum total field reaches 1.85 T at the minimum gap and 1.66 T at the FEMTOSLICING operation gap. The size of the poles, the carriage and the girders were optimized to minimize the deformation resulting from the magnetic forces (8 tons at minimum gap).

INTRODUCTION

The SOLEIL FEMTOSLICING [2] is a multi–user project focused on the production of ultra-short photon pulses (~100 fs). It is based on the exchange of energy resulting from the interaction inside a wiggler ("modulator") and an external short pulse laser. The wiggler resonant wavelength matches the 790 nm laser wavelength. The other specificity of the SOLEIL modulator is that it is also used as a high energy photon source (10 keV to 70 keV) for the PUMA beamline [3]. The construction of W164, gathers thus two goals. The first is to reach low photon energy which is not the predilection spectral range of medium/high energy storage rings such as SOLEIL. The second is to operate the modulator at high critical energy. Both constraints require building a wiggler with high field and large period.

DESCRIPTION OF THE WIGGLER

Magnetic Design

The magnetic system is composed of 20 periods of 164.4 mm generating a maximum field of 1.85 T at a minimum gap of 14.5 mm. Each period consists of NdFeB permanent magnets and Vanadium Permendur poles assembled on aluminum holders and mounted on two aluminum beams (Fig. 1). The magnetic field is changed by moving the gap between the jaws from 14.5 to 240 mm. Special cares has been taken in the design of the carriage to avoid excessive deformations which result from high magnetic forces between magnet arrays (up to 8 tons). Thanks to the stiffness of the girders (300 mm), the rigidity of the frame and the small transverse size of the poles (50 mm), their planarity and parallelism remain within 0.1 mm under load.

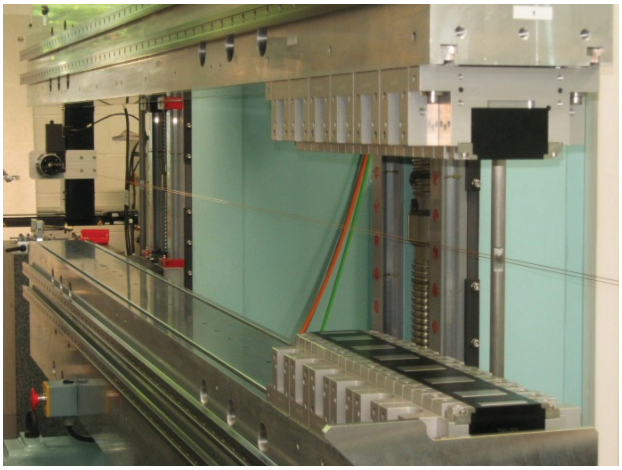

Figure 1: W164 during assembling.

However, the small transverse size of the poles impacts strongly the transverse homogeneity of the magnetic field and generates an off-axis strong field integral ("Dynamic field integral") [4] which could be responsible for nasty effects on the beam dynamics.

COMPENSATION SYSTEM

Four dedicated systems were designed and built at SOLEIL to compensate for the off-axis vertical dynamic field integral (Fig. 2. Left). Each of them is composed of four vertically polarized permanent magnets mounted in an aluminum holders (Fig. 2. Right). This system enables to reduce the maximum value of the vertical dynamic field integral from ±50 G.m to ±5 G.m, inside the vacuum chamber physical aperture.

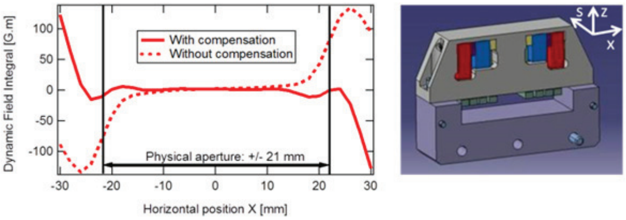

Figure 2: Calculated reduction of the dynamic field integral (Left) resulting from the effect of the compensation system (Right) at minimum gap (14.5 mm).

MAGNETIC MEASUREMENTS

Hall Probe Measurements

The magnetic field is measured with a Hall probe system moving along the wiggler axis in order to determine the gap (FEMTOSLICING operational gap) corresponding to a resonant energy of 790 nm. The magnetic field reaches 1.85 T at the minimum gap and 1.66 T at the 16.7 mm FEMTOSLICING operation gap (Fig. 3).

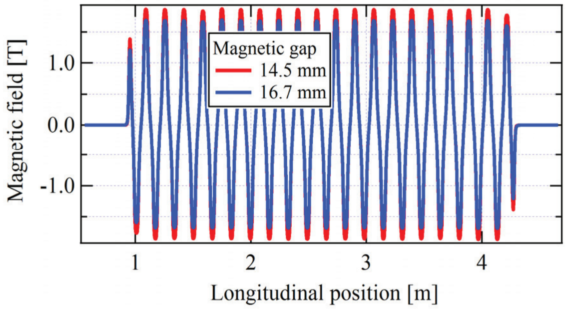

Figure 3: Measured magnetic field of W164 at minimum gap (14.5 mm) and FEMTOSLICING operational gap (16.7 mm).

Field Integral Measurements

Field integral measurements enable to deduce the kick angle experienced by the electron beam at the exit of the wiggler which should vanish if the wiggler is perfect. A six meter air coil travelling transversally in the median plane of the wiggler is used to evaluate both the residual horizontal and vertical field integrals and their transverse homogeneity. Magnetic corrections have been performed first without the compensation system using a first set of magic fingers. This led to an almost perfect Insertion Device, for all gaps, in terms of first order field integrals transverse variation. Secondly, the wiggler has been optimized with the compensation system, especially at the FEMTOSLICING operational (16.7 mm) gap. Due to some unexpected magnetic behavior of the compensation system, a second set of magic fingers has been used to help for the dynamic field integral compensation (Fig. 4).

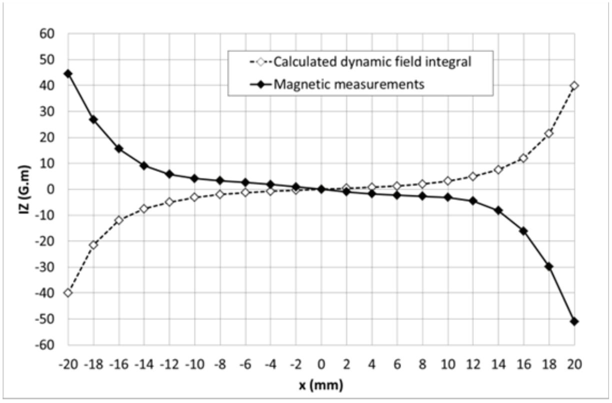

Figure 4: Optimization of the transverse variation of the vertical integrated field at the FEMTOSLICING operational gap using the compensation system.

This has resulted in some large harmonic components at higher gaps (above 30 mm) which however are not problematic because the wiggler operates at fixed gap.

COMMISSIONING

Machine Operation

The characterization of the wiggler using the electron beam has started just after its installation in the ring in October 2013. The 14.5 mm minimum gap is no more available on the machine because of the vertical tuning of the wiggler poles and becomes 14.7 mm which is still fully satisfying for the PUMA beamline experiments. It has been verified first that the wiggler can be closed at minimum gap with a 500 mA stored beam current without damaging the front end absorber. Then, the wiggler has been prepared for the FEMTOSLICING operation at 16.7 mm gap: in order to restore the nominal optics, a local correction of the strong vertical tune shift (+ 0.01) and β-beating (± 5 %) has been performed. The effects on the main electron beam parameters have been measured as a function of gap. As expected, due to the high field value of the wiggler and the non-zero dispersion function value at the wiggler location, the horizontal emittance is increased by 10 % (7.5 %) at 14.7 mm (16.7 mm) gap. A very good agreement with expected values from magnetic measurements has been found in terms of additional focusing (Fig. 5).

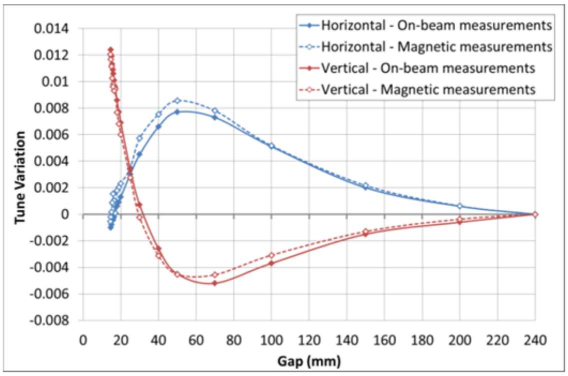

Figure 5: Horizontal and vertical tune shifts generated by the wiggler as a function of gap and comparison with expected values from magnetic measurements.

To study the efficiency of the compensation system on nonlinear dynamics, the effect of the wiggler on beam lifetime and injection rate has been measured. The injection efficiency has been measured on the bare machine and without restoring the nominal optics at each gap (Fig. 6). It is affected for gaps smaller than 50 mm but remains acceptable even at minimum gap. The effect of the wiggler on beam lifetime (Fig. 7) has been measured during the first closing of the wiggler gap with a total stored beam current of 500 mA and with constant betatron tunes like in operation and the horizontal emittance growth contribution has been deduced. A strong beam lifetime drop starts from 130 mm gap but is slowed down at 80 mm gap and the lifetime finally

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stabilizes for gaps smaller than 50 mm. It seems that the compensation system operates adequately and reduces enough the dynamic field integral in such a way that the beam lifetime is not destroyed. To verify this interpretation, some experiments will be performed soon to study with the beam the effect of the wiggler without the compensation system.

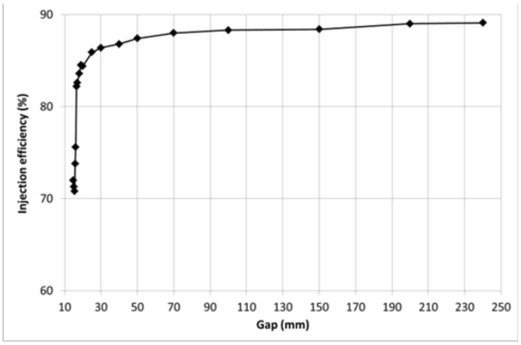

Figure 6: Effect of the wiggler on the injection efficiency as a function of the gap.

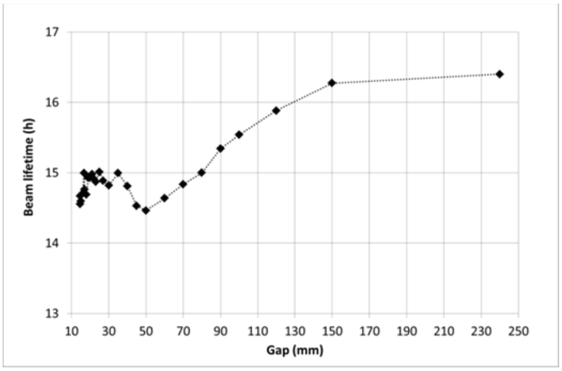

Figure 7: Effect of the wiggler on the beam lifetime as a function of the gap. Measurements have been performed with a 500 mA stored beam current.

FEMTOSLICING Experiment

Because the FEMTOSLICING experiment relies on the interaction between the electron beam and a short pulse laser in the wiggler, the laser has to be aligned on the electron beam in the spatial, temporal and spectral domains. In the PUMA frontend, a removable mirror enables to extract both the laser and the wiggler synchrotron radiation for analysis on an Infra-Red (IR) diagnostics station [5]. Before initiating the alignment procedure, the wiggler synchrotron radiation was observed in the far field. As illustrated in Fig. 8, the measured patterns as a function of gap were found in very good agreement with simulations. Regarding the alignment of the laser, a f=2.5 m focusing lens with a CCD mounted on a translation stage are used to image the source point along the wiggler. Moreover, as illustrated in Fig. 9, the imaging results were found in good agreement with simulations performed with SRW [6]. Using a spectrometer, we confirmed that the 16.7 mm gap enabled to adjust the resonance wavelength at the targeted wavelength of 790 nm.

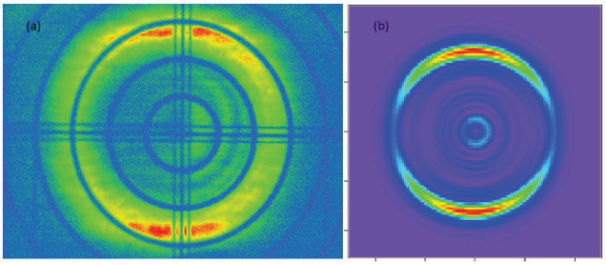

Figure 8: Synchrotron radiation pattern measured (a) and calculated with SRW (b) 12 m downstream the wiggler at 20 mm gap. Bandpass filters select the 700 – 900 observation range.

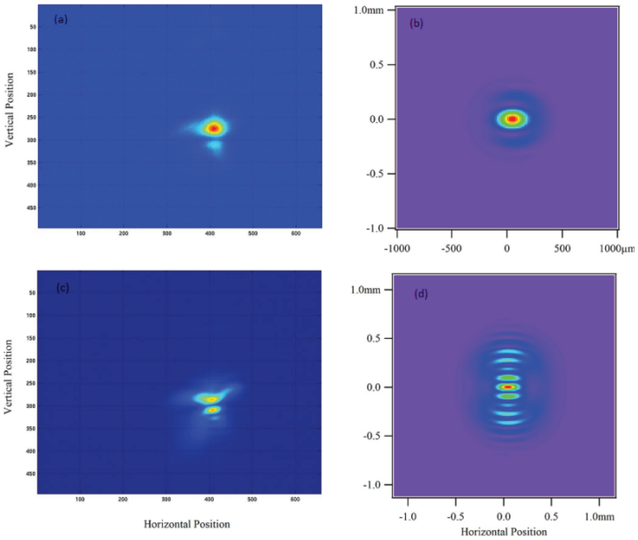

Figure 9: Source point in the wiggler, imaged at gap (Top) 16.7 and (Bottom) 19 mm, with a f=2.5 m lens. Bandpass filters select the 700 – 900 observation range. (Left) Measurement, (Right) SRW simulation.

CONCLUSION

The W164 wiggler has been designed, built and installed at SOLEIL for both the FEMTOSLICING operation and the high energy experiments PUMA beamline. The device has been characterized using both electron and photon beams and is presently ready to provide energy exchange and to start the beamline commissioning.

REFERENCES

[1] A. Zholents and Zoloterev, Phys. Rev. Let. 76, p. 912 (1996).
[2] A. Nadji et al., Proc. of EPAC2004 conference, Lucerne, Switzerland (2004), pp. 2332-2334.
[3] PUMA website: http://www.synchrotron-soleil.fr/Recherche/IPANEMA/methodessynchrotron#puma
[4] J. Safranek et al., Phys. Rev. ST Accel. Beams, 5, 010701 (2002).
[5] M. Labat et al., these Proceedings.
[6] O. Chubar, P. Elleaume, Proc. of EPAC1998 conference, pp.1177-1179.