Study of transverse beam instabilities in the SOLEIL II synchrotron booster

Watanyu FOOSANG

(Groupe Physique des Accélérateurs, Synchrotron SOLEIL, Gif-sur-Yvette)

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THÈSE

SOLEIL is a French third-generation synchrotron light source opened to users in 2008. Despite its impressive performance in delivering stable high-brightness photon beams during the past 20 years, it is undergoing an upgrade plan called SOLEIL II towards a fourth-generation light source (4-GLS) to meet the needs of new research domains of the following decades. The SOLEIL II's electron beam natural emittance will be drastically reduced to about 83 pm rad, compared to 3.9 nm rad in the present machine, to reach the diffraction limit in the soft/tender X-ray range. To achieve this ambitious beam emittance, strong focusing magnets must be employed, which will increase the machine's natural chromaticity as a consequence. Strong sextupoles therefore must be used for intense chromatic correction. The vacuum chamber apertures will then have to be reduced in order to decrease the magnetic gaps and help for strong field production. The Multibend Achromat (MBA) lattice design which packs a number of magnets in one cell is usually opted for a 4-GLS construction. For SOLEIL II, a 16BA and a hybrid 7BA-4BA are chosen for the booster and the storage rings, respectively. For the booster, the new lattice is foreseen to bring many challenges regarding collective instabilities. First, the reduction in the vacuum chamber aperture size will surely increase the resistive-wall impedance, usually the largest contributor to the impedance budget due to the long machine circumference. A small vacuum chamber also means that an element like the beam position monitor (BPM) will be closer to the beam, thus increasing the geometric impedance. Moreover, the effect of the strong sextupoles on the beam instabilities is also not certain. For these reasons, the collective effects in the booster must be profoundly studied to ensure the good functioning of the new facility. This thesis focuses on the study of transverse beam instabilities in the SOLEIL II booster including the transverse mode coupling, head-tail, resistive-wall, and beam-ion instabilities. We utilize a newly designed booster ramp model that considers the variation of equilibrium parameters along the ramp, permitting a thorough simulation of the booster. The chromaticity along the current SOLEIL booster's ramp was also measured for the first time since 2009 to validate the model. The preliminary SOLEIL II booster impedance model was constructed for the first time since the beginning of the project during this thesis. The growth rate and/or the threshold of each instability in various situations are determined, and the potential of Landau damping is also assessed in the framework of the new booster. In addition, as the betatron coupling is planned to be employed at the booster's extraction, an interesting question as to how the coupling will affect the transverse single-bunch instabilities is also investigated.

Les membres du jury sont :

Mauro MIGLIORATI	University of Rome 'La Sapienza'	Rapporteur
Giovanni RUMOLO	Ecole Polytechnique Fédérale de Lausanne	Rapporteur
Phillip BAMBADE	CNRS/IJCLab, Université Paris-Saclay	Examinateur
Christelle BRUNI	CNRS/IJCLab, Université Paris-Saclay	Examinatrice
Eléonore ROUSSEL	CNRS/PhLAM (UMR 8523), Université de Lille	Examinatrice