3rd SESSION : LANDAU cavities
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A. Anghel, M. Pedrozzi and M. Svandrlik reported about the SUPER-3HC Project, a collaboration work between CEA Saclay, CERN, PSI and Sincrotrone Trieste, which is now close to its outcome. The objective of this project was the design, fabrication, installation and commissioning of two identical superconducting (sc) 3^{rd} harmonic RF systems, one for the SLS, the other one for ELETTRA, with the purpose of improving the beam lifetime and stability.
The cryomodule, designed by the CEA Saclay, contains two passive 1.5 GHz Nb/Cu single-cell-cavities, operated in a LHe bath at 4.5 K. The parasitic HOM impedances are strongly damped (below the coupled bunch instability thresholds) by means of six HOM couplers (two for the longitudinal modes and four for the transverse modes), located on the tube connecting the two cells. The cavities with their He tanks were fabricated at CERN and the complete cryomodule was assembled and tested at CEA Saclay. The measured static losses of about 8 W and the quality factor ($Q_o = 2.6\ 10^8$ at 4 MV/m) well agreed with the expectations.
The cryogenic source is a HELIAL 1000 Helium refrigerator-liquefier from Air Liquide, which consists of a screw compressor with oil removal unit, a turbine-cold-box and the associated control-command system.
The first cavity cryomodule and cryogenic plant were installed in the SLS during May-June 2002. The site acceptance tests of the cryogenic source were successfully performed on a dummy load (dewar with internal heater) beginning of July. The achieved performance (simultaneously 10 L/hr of liquefaction and 150 W of refrigeration at 4.5 K with a compressor HP of 15 bar) largely exceeded the specifications. The first attempt of cavity cool down pointed out the need to insert two non-return valves in the transfer line circuit in order to prevent thermo-acoustical oscillations (Taconis). The cryomodule was finally cooled down and ready for operation end of September 2001.
During the June - September period the cryomodule was operated in the “warm and detuned” state with 200 mA of beam current. Above this current threshold, a HOM from a normal conducting (nc) 500 MHz cavity was driving a longitudinal multibunch instability. Since September, the cryomodule is operated cold with the cavity resonant frequency adjusted such that a beam of 400 mA induces a voltage of about 700 kV at 1.5 GHz, while the nc system generates 2.1 MV at 500 MHz. Under these conditions, it became possible to store up to 400 mA of beam perfectly stable. As expected, the 3^{rd} harmonic system produces a significant amount of Landau damping which contributes to stabilise the longitudinal multibunch instabilities. Rather surprising is the observation of a stabilising effect in the transverse plane as well; that is under investigation.
The measured bunch lengthening (factor 3) and the resulting increase in beam lifetime (factor 2.3) are also in good agreement with the expectations. The preceding results were obtained with a gap of 20% empty buckets in the bunch train, that induced up to 30 degrees of phase slip along the bunch train.
The ELETTRA SUPER-3HC system is also close to completion. The delivery and installation of the whole equipment were performed, in time. On the other hand, a series of problems were encountered during the first attempts of cavity cool-down (failure of components in the transfer lines, refrigerator turbine damage due to a missing protection interlock, contamination of the cold box) and that delayed the operation with cold cryomodule. In the mean time, the operation at 2.4 GeV - 200 mA could be pursued with the cryomodule in the “warm and detuned” state, whereas it made prohibitive the operation at 2 GeV - 320 mA due to the interaction between the detuned cavity fundamental mode and the beam spectrum, causing the excitation of a coupled bunch instability.
The next cavity cool-down is scheduled for the beginning of January 2003.

V. Serrière reported about longitudinal beam dynamics with harmonic RF systems. The usual analytical approaches of the collective phenomena (microwave, Robinson or longitudinal HOM-driven instabilities) in the presence of a single RF system are based on a linear approximation of the synchrotron motion. This is not valid for the case of a double RF system (fundamental + harmonic) since the bunch lengthening generated by the harmonic system is accompanied by non-linearity that leads to a significant spread in the synchrotron frequency of the electrons in the bunch. This spread in synchrotron frequency has a stabilising effect on the synchrotron oscillations, the so-called "Landau damping".
Another important aspect, difficult to include in the analytical models, is the transient beam loading phenomena, caused by a gap of empty buckets in the bunch train. The resulting phase slip along the bunch train can dramatically limit the bunch lengthening performance of the harmonic RF system.
A multi-bunch multi-particle tracking code has therefore been developed for computing all these effects. The result of the simulations performed with this code well agree with the experimental data from operating harmonic systems. They allow to better interpret the behaviour of these systems like for instance the strong transient effects and poor bunch lengthening obtained in BESSY-II and ALS, as well as the dramatic Landau damping observed in MAX-II.
This computer code also allowed to investigate thoroughly the possible performance of a harmonic system in the ESRF and to select the appropriate solution amongst different options: nc and sc cavities, operated either in passive or active mode. It turns out that the use of a pair of sc cavities, operated at the ESRF third harmonic frequency (1.056 GHz) and powered with about 60 kW, would be a suitable solution. According to the computations, such a system would improve the lifetime from 10 hours up to 30 hours with a stored beam of 90 mA in 16 bunches and from 5 hours up to 10 hours with 20 mA in a single bunch.

W. Anders reported about the status of the Laudau cavities and the Horizontal Bi-Cavity Test Facility (HOBICAT) at BESSY.
Four 3rd harmonic (1.5 GHz) nc Laudau cavities are routinely used for the standard user operation of BESSY II. With a beam current of 200 mA, a voltage of 50-60 kV is induced in each cavity, that lengthens the bunches by a factor of 1.3 and increases the beam lifetime by about 20%. The parasitic HOM impedances are damped below the instability thresholds by means of three waveguides containing ferrite absorbers.
It is planned to replace the previous nc system with a single sc Landau cavity of the Cornell type (HOM damped by means of ferrite absorbers, located in the cavity cut-off tube). Its cryostat, manufactured by ACCEL, should be delivered by spring 2003 and installed in the storage ring by the end of 2003. The cryogenic plant (perf ?), ordered at Linde, should be commissioned in summer 2003. The operation of the complete system is scheduled for the beginning of 2004.
HOBICAT is a liquid Helium cryogenic source facility with a refrigeration power capability of 80 W at operating temperatures of 1.5-2.2 K and 4.2 K for multi-purpose uses in BESSY: tests of the Tesla cavities, tests of BESSY FEL equipment and any other cryogenic developments. The RF power source will be a 1.3 GHz - 110 kW klystron amplifier. This facility should be available in 2004.