A SYNCHROTRON RADIATION BEAMLINE INSTALLED AT BINP TO STUDY THE HIGH LUMINOSITY LHC VACUUM SYSTEM

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Abstract

In the framework of the HL-LHC project, the vacuum performance of new surface material needs to be studied. In particular, a-C coating is proposed as an anti-multipactor surface for the HL-LHC superconducting final focusing system. Since the protons will generate synchrotron radiation (SR) with ~ 10 eV critical energy and ~10^{16} ph/m/s flux, it is therefore of great importance to study the impact of such photons on a-C coating held at room and cryogenic temperature and compares the results against present LHC material. This paper describes the construction and the parameters of the experimental set-up based on a new Synchrotron Radiation beamline of the BINP booster synchrotron, BEP. The experimental program done in collaboration between CERN and BINP, to perform measurements of photon stimulated gas desorption, photon distribution and photo-electron emission provoked by synchrotron radiation is also presented.

INTRODUCTION

The CERN Large Hadron Collider (LHC) is currently operating at nominal luminosity with proton-proton collisions at 13 TeV in the center of mass. Its upgrade, the High Luminosity LHC (HL-LHC), is designed to provide about 10 times more integrated luminosity with the aim to achieve ~3000 fb^{-1} by the mid-2030ies [1]. To do so, the circulating current is doubled, the beam size and the crossing angle at the collision point are further reduced to achieve a desired levelled luminosity five times larger than the LHC nominal luminosity.

In these storage rings, the vacuum system is subjected to synchrotron radiation (SR) and electron bombardment due to the build-up of an electron cloud. In particular, the vacuum level in the vicinity of the experimental areas should be kept to a minimum in order to maintain the beam induced background to acceptable values. In HL-LHC, the final focusing system consists of three superconducting quadrupoles, so called “Inner Triplets”. The vacuum system houses a shielded beam screen, operating in the ~60 K range, which intercepts the debris produced at the interaction point, thereby protecting the 1.9 K cold mass from radiation damage.

In the context of the HL-LHC project, the vacuum performance of new surface material needs to be studied in details. In particular, amorphous carbon (a-C) coating [2,3] is proposed as an anti-multipactor surface with the objective to minimize the heat load induced by the electron cloud on the shielded beam screen and the background to the experiment due to proton scattering onto the residual gas. Since the protons in the HL-LHC Inner Triplets generates SR with ~ 10 eV critical energy and ~ 10^{16} ph/m/s flux, it is therefore of great importance to study the impact of such photons on a-C coating held at room and cryogenic temperature and compare the results against present LHC material.

The new beam line facility, presently under construction at BEP, BINP, provides SR irradiation at ~10 mrad grazing angle with 10-1300 eV critical energy and ~$5\cdot10^{16}$ ph/m/s flux. It is designed to study photon stimulated molecular gas desorption, photo-electron emission and photon reflectivity of candidate HL-LHC materials held at room and cryogenic temperature.

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SR BEAM LINE

BEP is the booster synchrotron of the collider VEPP-2000. The machine is part of the new injection complex at BINP. BEP was re-designed and reconstructed to operate with electron or positron at energies in the range 50 ÷ 1000 MeV, with a nominal operation at 300 MeV. Nevertheless, a continuous operation is possible up to 900 MeV. The main SR parameters of a BEP dipole magnet at electron energies 200, 300 and 900 MeV are shown in Table 1. They cover the range of parameters for LHC and HL-LHC.

Table 1. SR Parameters at Different Particles Energy in BEP

Parameter	min	nominal	max
E [MeV]	200	300	900
Beam current [A]	0.5	0.5	0.5
Bending magnet radii [mm]	1280		
SR critical energy [eV]	14	47	1260
SR flux [ph/mrad/s]	1.1E15	1.8E16	5.6E16
SR power [W/mrad]	0.009	0.045	3.6
SR vertical divergence [mrad] at Ec	2.5	1.7	0.56

EXPERIMENTAL INSTALLATION

A schematic diagram of the experimental set-up on the BEP SR Beam Line is shown in Figure 1. The main elements are: “P” – a pivot point to allow a precise tuning

ISBN 978-3-95450-181-6

of the irradiation at grazing incidence angle; “C” – a cone with a thermo-cathode to allow conditioning of measuring port [4]; EC – an end collector for the measurements of specular scattering; V – an all metal gate valve to isolate the beam line equipment from the experimental set-up; LV –a leak valve to perform gas injection for RGA calibration; RA&M – a movable radiation absorber and a mirror for interrupting and monitoring the SR beam. The SR Beam Line will also contain a collimator to control the horizontal and vertical sizes of SR beam.

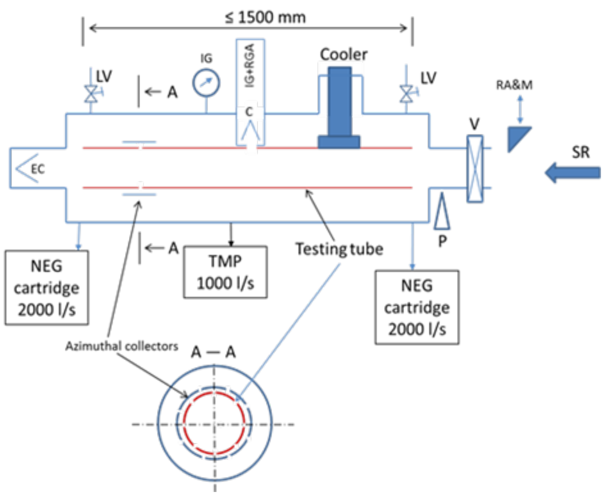

Figure 1: Experimental set-up.

The tested chamber is installed coaxially inside a tube with larger diameter. A pumping system consisting of two NEG cartridge pumps and a turbomolecular pump provides a very large pumping speed which simulates the large pumping speed of the Cold Bore (CB) in the 1.9 K cold beam pipes of HL-LHC. The objective is to achieve pressure level in the range 10^{-8} Pa or even less without baking.

Table 2. Parameters of the experimental set-up installed on the BEP SR Beam Line.

Parameter	value		
Max SR horizontal angle [mrad]	10		
Testing chamber max length [m]	1500		
Length of irradiated part of testing chamber	1300		
Coordinate of testing chamber inlet* [mm], pivot point	2100		
Horizontal SR beam size at testing chamber inlet [mm]	5	13	21
SR max. flux at Ec=47 eV	4.5E16	1E17	1.8E17
Incident angle [mrad]	5 ± 1.2	13 ± 3	21 ± 5

*relatively to SR generation point.

The chosen geometry allows a simple exchange of the tested chamber. The system is equipped with azimuthal collectors (10 pieces) placed behind holes produced in the tested chamber. The collectors allow for the measurements of azimuthal distribution of diffusely scattered photons (or distribution of photoelectrons in case of positive bias of the collectors relatively to testing tube). The system allows to cool the testing tube down to at least 60K (at least) with the use a standard cryo-cooler. Table 2 contains the main parameters of the experimental set-up.

EXPERIMENTAL PROGRAM

The first phase of the experimental program consist in the quantitative measurement of:

- photon stimulated molecular gas desorption with a calibrated residual gas analyser (RGA);
- photo-electron yield;
- forward reflectivity in SR power and photon flux units;
- azimuthal distribution of photoelectrons and azimuthal distribution of diffusely scattered photons.

The measurements will be produced in the following conditions:

- up to an accumulated photon dose > 10^{23} ph/m,
- with a SR incident angle of 10 mrad,
- at a SR critical energy in the accumulated photon dose mode in the range 40 ÷ 50 eV,
- scanning over SR critical energy at 10, 25, 50, 100, 200, 400, 800, 1300, 1700 eV at selected doses of 10^{21}, 10^{22}, 10^{23} ph/m,

These measurements will be performed at room temperature for two samples: uncoated and a-C coated OFE-Cu tubes. The geometrical dimensions are: inner diameter = 40.5 mm, thickness 2.5 mm, length 1500 mm. The followed experimental program and system parameters will be the same for both sample.

A second round of experiment will be later repeated for some of the most interesting measurements in the temperature range 60 ÷ 300K.

CONCLUSION

A new experimental set-up produce on the new BEP SR Beam Line will provide detailed investigation of vacuum properties of prototypes subjected to high intensity SR. With this device, the accumulated photon dose will be comparable with SR dose expected in the HL-LHC experimental areas after about one-year operation.

ACKNOWLEDGMENT

The authors would like to thank J-M. Jimenez, O.B. Malyshev, Yu. Rogovsky for helpful discussions and support to the project. They would like also to warmly acknowledge P. Costa-Pinto and A. Sapountzis for the a-C coating of the tested tube.

ISBN 978-3-95450-181-6

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ISBN 978-3-95450-181-6