START-UP OF THE NESTOR FACILITY VACUUM SYSTEM

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Abstract

The Kharkov X-ray generator NESTOR based on Compton backscattering is under commissioning. The vacuum system of the complex integrates a linear accelerator-injector, the beam transport channel and the electron storage ring with energy range from 40 to 225 MeV.

Elements of vacuum chambers, pumping facilities, cleaning surfaces procedures are described. Chambers are made of stainless steel (SS). Residual vacuum pretesting pressure of 5×10^{-9} Torr in the storage ring chambers has been achieved.

INTRODUCTION

The vacuum system of the X-ray generator NESTOR consists of three functional parts:

- Vacuum system of the storage ring NESTOR with electron beam energy up to 200 MeV and circumference of 15.9 m;
- Vacuum system of the transportation channel of 5.6 m long;
- Vacuum system of the linear accelerator injector with electron beam energy up to 90 MeV and total length of about 10 m (two SLAC type accelerating sections with 3 m length).

The storage ring vacuum system should provide the value of the electron beam life time not less then 0.5 hour at 60 MeV and not less then 2 hours at 200 MeV electron beam energy [1]. To provide such requirements the average value of the residual gas pressure in presence of the electron beam and, therefore, synchrotron radiation should be better then 5×10^{-9} Torr.

Transportation channel vacuum system provides the trespassing of the electron beam from the entrance of the electron accelerator, trough the transportation channel with its collimator and focusing elements, fridge field of the first storage ring bending magnet to the injector sector of the NESTOR storage ring [2]. The adjustment of the residual gas pressure value in the linear accelerator ($P_{inj} \geq 5 \times 10^{-7}$ Torr) and storage ring ($P_{sr} \geq 5 \times 10^{-9}$ Torr) should be done in the transportation channel vacuum chamber. To match these two pressures three steps differential pumping system has been realized at the injection channel. The system includes two diode pumps with 100 l/s and 250 l/s pumping capacities and one triode pump with 150 l/s pumping capacity. Such scheme of the pumping allows to decrease a value of the residual gas pressure on three order from the linear accelerator to the storage ring.

The generally used way to produce the required vacuum value ($\sim 10^{-10}$ Torr) in the high energy storage rings (3-6 GeV of electron beam energy) and in storage rings with lower beam energies (500 MeV – 1 GeV) to use localized (ion) as well as distributed (getter) vacuum pumps due to high power loading of the synchrotron radiation at walls of vacuum chambers. Despite the fact, that the power loading at the walls in the low energy storage rings are not so crucial, it can prevent to reach the value of the design required pressure.

VACUUM SYSTEM SCHEME AND LAYOUT

Pumping Units Choice

In general, the pressure value P in vacuum systems can be determined with summarized pumping speed S and integral outgassing flux Q as a follows:

$$P = Q / S.$$

For short and small aperture vacuum systems such as storage ring vacuum chambers and NESTOR chamber in particular the total pumping speed is determined with the number of pumping units along storage ring circumference and with the pumping speed of each pump.

In Fig. 1 the NESTOR injector channel and storage ring magnetic lattice, and layout of the vacuum system with pumping units are shown.

Figure 1: The lattice of X-ray generator NESTOR injection channel and storage ring with layout of vacuum system.

The magnetic lattice consists of 4 dipole magnets, 20 quadrupole and 18 sextupole magnets with total circumference of 15.6 m. Due to dense layout of the elements installation there is a lack of room for the vacuum equipment placing. In addition, due to small vacuum chamber aperture (79×27 mm^2) the vacuum conductivity of the chamber is limited, that makes unreasonable to use of pumps with high pumping speed.

The NESTOR vacuum system includes the following pumping units (see Fig. 1):

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I – Varian turbo-molecular pump and ion diode pump with cryo-panel;

II, VII – combined diode pump with spread getter;

III, VI – ion diode pump;

I, IV, V, VIII – ion diode pump and getter pump;

I, V – VARIAN ion triode pump with cryo panel and spread getter.

The injection channel has the following pumping units:

1, 2, 3 – ion diode pumps;

4 – the first pump of the storage ring.

The characteristics of the NESTOR pumping unit are presented in Table 1.

Table 1: Main Characteristics of NESTOR Pumping Units

#	N	Type	Pumping speed, l/s	Pressure limit, Torr
I	1	Turbo-mol	250	$<10^{-9}$
I, V	2	triode	150	$<10^{-9}$
I, V	2	getter	515	$<10^{-9}$
II, VII	2	Diode with getter)	100-iode, 300-getter	$<10^{-9}$
III, IV, VI, VIII	4	diode	150	$<10^{-9}$
I, IV, V, VIII	4	getter	300	$<10^{-9}$
1, 3, 4	3	diode	100	$<10^{-9}$
2	1	diode	250	$<10^{-9}$
Total	19			

All pumping units are oil free. The limit pressure values of the residual gas each pumping unit can provide are shown in Table 1 and as one can see they are not better then 10^{-9} Torr. To provide the project required pressure values one should provide vacuum clean inner surfaces of the vacuum chambers, decreasing of thermo-desorption, elimination of vacuum leakages.

Calculations show that outgasing level in NESTOR facility will be about 5×10^{-12} (Torr ×l) / (cm^2 × s) that with all pumping units mentioned above gives a possibility to get 10^{-9} Torr value of the residual gas pressure.

DIPOLE MAGNET VACUUM CHAMBER

Fig. 2, 3 show the drawing and photo of the dipole magnet vacuum chamber of the NESTOR facility. Four sapphire vacuum windows are installed in the chambers to provide synchrotron radiation extraction from each chamber.

The camera includes:

1 – channel of the circulating electron beam;

2 – vacuum pumps flanges,

3 – synchrotron radiation channel;

4 – Compton X-ray channel;

5 – getter pumps and mass-spectrometer flanges;

6 - baking system.

The camera is manufactured as two argon welded mirror symmetry parts. Camera has a lot of intrinsic reinforcing ribs.

Taking into account the difficult shape of the intrinsic vacuum chamber configuration the total scheme of the chamber vacuum cleaning includes the following stages: rough mechanical cleaning, degreasing, baking in - situ with temperature of 150 - 180ºC, glow discharge cleaning in helium or argon with small amount of oxygen medium, synchrotron radiation beam cleaning during facility operation.

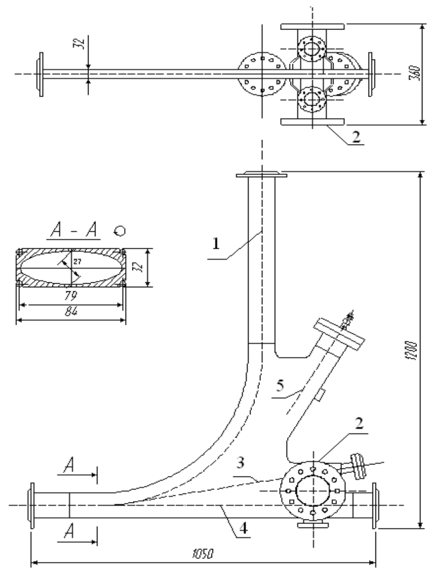

Figure 2: Dipole magnet vacuum chamber drawing.

Figure 3: Dipole magnet vacuum chamber view.

VACUUM CLEANING TECHNOLOGY

To provide preliminary preparation of the vacuum surfaces the following procedures were made:

- blow of the details with compressed air;
- high pressure washing with hot water (degreasing, emulsion and mechanical cleaning etc);
- alkali washing with use of ultrasonic washing;
- demilitarized hot water rinsing;
- hot vapors cleaning with temperature of 120ºC) with further ultrasonic washing;
- drying with hot vapor of nitrogen and air;
- hermetic packing.

To provide the operations mentioned above were used sodium Na_2CO_3, caustic soda NaOH, ultrasonic generator

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RETONA; boiler (70ºC); distillatory, oil free compressor, high pressure washing machine, discharging equipment, argon, helium, nitrogen, oxygen and other equipment.

RESULTS OF THE SYSTEM ASSEMBLING AND TESTING

During 2012 year the vacuum system of the transportation channel and storage ring were assembled and tested. The system was checked with mass spectrometers and leak finder. The system was pumped and provided average value of residual gas pressure equal to 10^{-8} Torr.

During the commissioning of the NESTOR facility, accelerator and injection tests the system showed good stability with pressure value of 10^{-8} Torr.

To provide design value of the residual gas pressure the vacuum chamber baking will be used.

Figures 4-7 show the elements of NESTOR facility vacuum system.

Figure 4: NESTOR RF cavity installed in the ring.

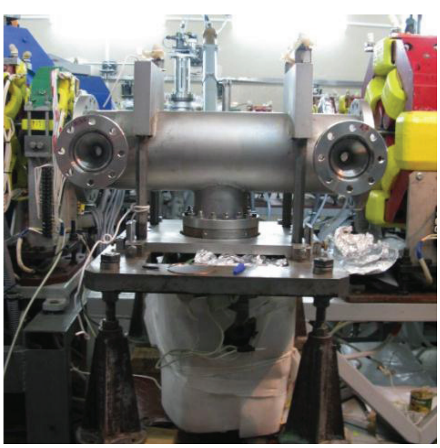

Figure 5: NESTOR inflector vacuum chamber before installation.

Figure 6: NESTOR interaction section.

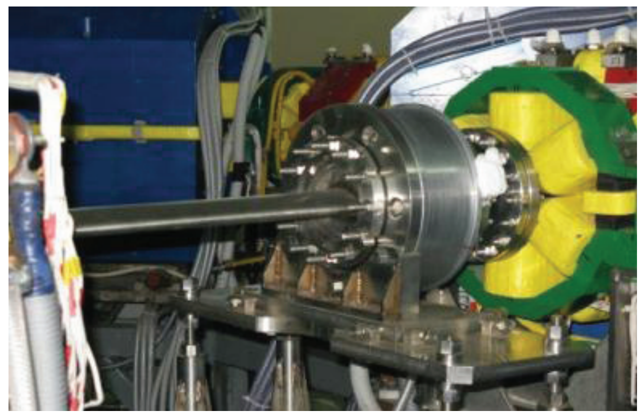

Figure 7: NESTOR ACT.

CONCLUSION

In 2012 NESTOR facility vacuum system was prepared, assembled and tested. During first facility tests with injected electron beam the system showed stable parameters with pressure value equal to 10^{-8} Torr.

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