# VACUUM CHAMBER DESIGN CONSIDERATIONS FOR CANDLE LIGHT SOURCE

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*Abstract*

The main considerations of the vacuum chamber design for CANDLE light source are presented. The design is based on the stainless steel vacuum chamber that has been successfully adopted for number of operating light sources. The main geometrical, mechanical and impedance issues for the chamber design are discussed. An antechamber concept adopted for CANDLE storage ring is presented. The beam line and pumping port distributions along the ring are analysed.

## 1 VACUUM CHAMBER DESIGN

The vacuum system of the accelerator is composed of three basic sub-systems: vacuum chamber, pumping and control systems. The vacuum system for the CANDLE storage ring has to provide the required vacuum pressure of about 1 nTorr in order to achieve integrated beam lifetime about 20 hours with the beam current in the ring of 350 mA. For achievement of the design goals, selection of the material for fabrication of the vacuum chamber has a great importance.

For the intermediate energy light sources, the stainless steel is a good vacuum chamber material. The stainless steel material has excellent vacuum properties [1]. The stainless steel has low magnetic permeability µ• 1.005, high density and mechanical strength (longitudinal tension R=300 N/mm²). The stainless steel can be well machined (manufactured) and easily be welded. The use of stainless steel for manufacturing of vacuum chamber efficiently simplifies the technology and reduces the prime cost.

The technological approach to vacuum chamber in the third generation storage ring is an important factor enabling achievement of necessary low pressures in vacuum chamber. It requires a systematic approach and physical investigations. In order to attain high vacuum in the storage ring chamber and to prevent the desorption process provoked by photons, the vacuum chamber is divided into two zones: in one the electrons will circulate and the second will deal with synchrotron radiation. The features of this solution are described below.

The main vacuum chamber of storage ring consists of 16 identical parts (number of magnetic lattice periods), which are connected by bellows junctions. Each period is divided into four sections that correspond to two dipole sections (sector 1, sector 3), focusing section (2) and erect section (4). The sections are connected by conflate flanges with smooth contact surfaces. The main geometrical parameters of the vacuum chamber are presented in Table 1.

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Table 1: Main parameters of the vacuum chamber

| | |
|---|---|
| Vacuum [nTorr] | 1 |
| Material | Stainless steel |
| Thickness of the sheet [mm] | 3 |
| Interior dimensions of electron Channel [mm] | 30 x 74 |
| Gap [mm] | 12 |
| Minimal width [mm] | 150 |
| Maximal width [mm] | 320 |
| Maximal length of one section [mm] | 3506 |

The general view of the vacuum chamber together with the magnetic elements for one standard period and the photon beam line ports is shown on Figure 1. Each section has the pumping port. The sections that serve the extracted photon beam lines and where the synchrotron radiation is basically observed have the antechamber and the absorber stations.

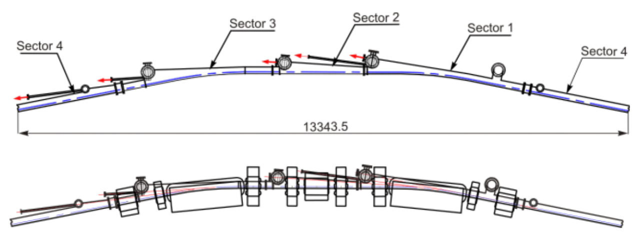


Figure 1: Standard section of vacuum chamber layout.

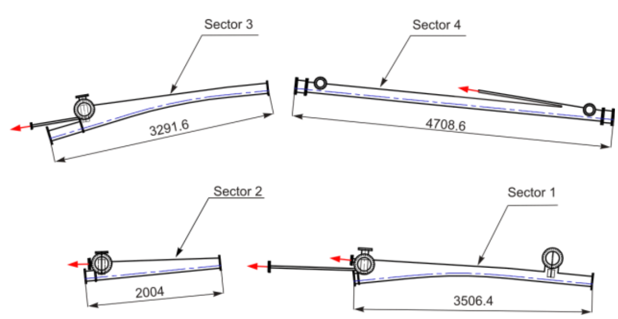


Figure 2: Plan view of vacuum chamber sections.

The chamber plan-view geometry at the different sectors of the lattice is shown in Figure 2. Sector 1 (length 3.506 m) can provide an extraction of two photon beam lines: from the dipole BM01a and insertion device ID02, the sector 2 (length 2.004 m) can provide one photon beam line from dipole magnet BM01b, keeping the possibility for installation of insertion device and corresponding beam line from wiggler or undulator in contiguous erect sector; sector 3 can provide one photon beam line from the dipole BM02a, sector 4 can provide one photon beam line from the dipole BM02b.

A characteristic feature of vacuum chamber in dipole section is the use of the antechamber design. The vacuum chamber consists of an electron beam chamber and an antechamber. The electron chamber is open to the side of antechamber. In the straight lines where synchrotron radiation power density is lower, the vacuum chamber is without antechamber. The electron chamber geometry is constant through the whole perimeter of the ring, while an antechamber width is variable and depends on the external contour of the chamber. Figures 3a and 3b show the cross sections of the vacuum chamber.

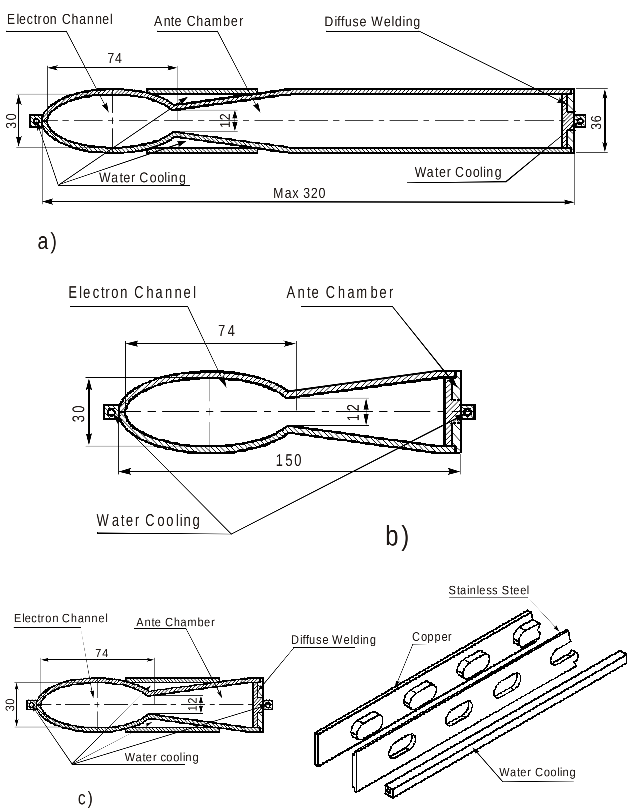


Figure 3: Cross-section of vacuum chamber: a) in first dipole magnet; b) in second dipole magnet; c) detail drawing of chamber vertical wall.

The electron channel of the chamber is implemented in the form of ellipse with internal dimensions of 30 mm in vertical and 74 mm in horizontal plane. As it is seen from the drawing, the electron channel is done of two symmetric halves, which are welded together longitudinally. The profiles of these halves are supposed to get by stamping with subsequent laser trimming of the edges. The weld seam is implemented using TIG (tungsten inert gas) welding along with the electron beam welding.

## 2 WATER COOLING AND ABSORBERS

For the cooling of the dipole magnet chamber, a water jacket is foreseen. It is formed between the placed up and down welded plates and the contour of the main profile. At the two ends of the chamber the water jacket is suppressed by blank flanges, to which pipe connections are welded, in a purpose to supply and remove water. On the backwall of antechamber and on the front wall of electron channel the rectangular copper pipes, which have a high thermal conductivity, are soldered for effective cooling of these areas. The last elements also increase the rigidity of the chamber.

In a purpose to provide a good thermal contact, windows are milled on the stainless steel backwall of the antechamber. Copper plates are welded to those windows by means of diffusion welding. When the square cooling copper pipes are soldered, a good thermal contact is provided in an obtained vacuum. The explosion is shown on Figure 3c.

For the photon beam extraction from the storage ring, the dipole magnet vacuum chamber has the expanded sections, the end-face of which is blanked off by flange on which the pipe of extraction channel is welded.

Similar section has also the chamber, where the focusing elements are installed. On these sections the pumping-out nodes are welded on front of the extraction channels. The common view of this junction is shown on Figure 4.

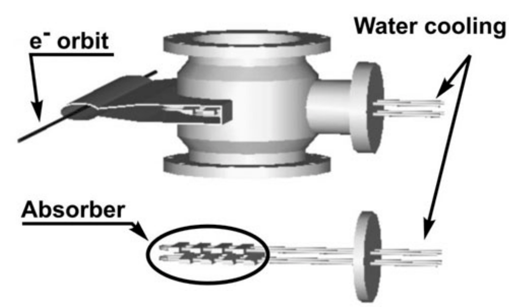


Figure 4: The chamber pumping port with the absorber.

The junction unit is a cylinder with three pipes, two of which (the upper and the lower ones) serve for connection of vacuum pumps, and the third one for installation of the cooling absorber. The absorbers are implemented in a form of copper plates with corrugated absorbing surfaces through which the copper cooling pipes pass. The profile of the absorber is implemented in such a way that it allows to close the surface from the direct radiation and to keep open an aperture for photon beam extraction.

## 3 CHAMBER MECHANICAL PROPERTIES

In the regions of vacuum chamber, which are free from the magnetic elements, the stiffening ribs made of stainless steel are welded. The calculations show that the maximal deflection in week section of the chamber doesn't exceed 0.5 mm. The results of calculation for the erect part of the vacuum chamber and for the vacuum chamber where the dipole magnet is installed are presented in Figure 5 and Figure 6 respectively.

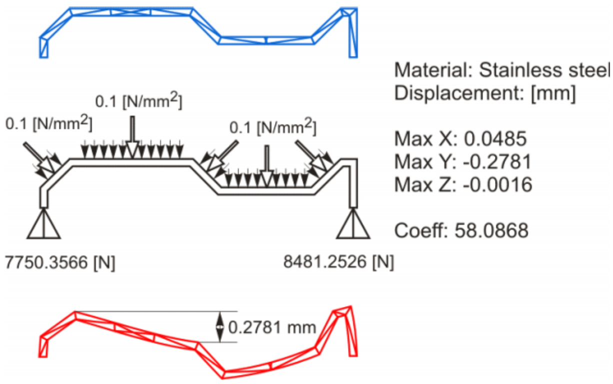


Figure 5: Deflection of the erect part of the vacuum chamber

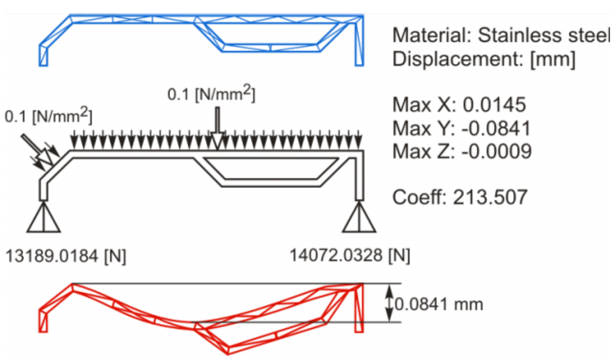


Figure 6: Deflection of the dipole magnet vacuum chamber.

The calculations have been done for upper half of the chamber profile. Loading is uniformly distributed and amounts 0.1N/mm², which corresponds to the pressure of 1 atmosphere. The internal pressure of the chamber is accepted absolute null. As one can see from the Figure 6 the section of the chamber where the dipole magnet is installed is stiffer due to the welded plates, which also serve for the formation of the water jacket. If the maximal deflection of the profile of vacuum chamber in the erect part is ~0.28 mm, then in a part where the dipole magnets are installed, it equals 0.08 mm, which is quite accessible.

## 4 PUMPING SYSTEM

The detail analyses of the economical, production, technological and exploitation factors associated with different pumping system options, lead to the external pumps approach for the CANDLE storage ring. This solution is the most cost-efficient in the stepwise construction of the complex and is the simplest scheme, which provides the demanded vacuum parameters.

The fore-vacuum pumping is performed with roughing-down pumps (2 units) and turbo-molecular pumps (16 units) since they have high rate of pumping [2]. This procedure is implemented along with preventing the oil penetration to the high-vacuum channel with the help of cryo-adsorbent. Gate valves are installed on each turbo-molecular pump, whose impermeability is supported by the metal gasket.

The principal pumping of the storage ring vacuum chamber is implemented with titanium sublimation pumps, connected to the photon absorbers. While the primary function of these pumps is to trap the gas from the photon absorbers, each pump offers 1200 liters/s or a total of about 100,000 liters/s for the entire ring.

Titanium sublimation pumps do not pump off methane and argon [3], so 64 StarCell sputter ion pumps are also distributed around the ring. The pumping rate of each station is 150 liters/s. These pumps are also designed for pressure measurement; thus they constitute 64 vacuum-measurement stations. The total amount of pumping of these NEG pumps is 10000liters/s. All the pumps can be isolated from the vacuum system of the ring with the help of gate valves, which have metal seals.

The main characteristics of pumping system are presented in Table 2.

Table 2: The components of pumping system.

| Type of Pumps | Quantity | Pumping rate/unit (liters/s) | Vacuum (Torr) |
|---|---|---|---|
| Fore-vacuum | 2 | 25 | $10^{-2}$ |
| Turbo-molecular | 16 | 600 | $10^{-6}$ |
| Titan-sublimation | 80 | 1200 | $10^{-8}$ |
| NEG | 64 | ~150 | $10^{-11}$ |

## 5 SUMMARY

The vacuum chamber design for CANDLE storage ring and the main approaches to pumping system are presented. The results of the study will be the bases for the prototype development and the vacuum test stand design. The R&D programm also includes the thermal analysis of the vacuum chamber under beam loaded conditions that will result on further optimization of the vacuum chamber performance.

## 6 REFERENCES

[1] A.A. Glazkov and G.L. Saksaganskii, “VACUUM of Electro-physical Facilities and Complexes,” (in Russian), Energoatomizdat, Moscow , 1985
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