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X-RAY LITHOGRAPHY SOURCE (SXLS) VACUUM SYSTEM*

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Summary

In 1988 Brookhaven National Laboratory (BNL) was awarded a contract to design and construct a compact light source for X-ray lithography. This award is part of a technology transfer-to-American-industry program. The contract is for an electron storage ring designed for 690 MeV-500 ma operations. It has a racetrack configuration with a circumference to 8.5 meters. The machine is to be constructed in two phases. Phase I (200 MeV-500ma) will primarily be for low energy injection studies and will incorporate all room temperature magnets. For Phase II the two room temperature dipole magnets will be replaced with (4T) superconducting magnets and operation will be at 690 MeV. This paper describes the vacuum system for this machine.

Vacuum System

Introduction

An X-ray lithography (XLS) source vacuum system must satisfy three basic requirements: First, it must provide a dynamic pressure (pressure with stored beam) of 10^{-9} Torr or better to minimize electron beam-residual gas interaction. Second, it must be able to recover from venting to atmosphere, deliberately or accidentally, in a reasonably short time. And third, it should require little operator intervention for normal operation.

Figure 1. is a plan view of the Phase I XLS storage ring. It shows the 8.5 meter circumference vacuum system with one diagnostic beam port (an operational XLS will have 10-20 beam ports depending on the system geometry). The vacuum system is fabricated from stainless steel type 304 L, the dipole chambers from INCONEL 625, and the rf cavity from OFHC copper. The system is designed for an operating pressure of 1×10^{-9} Torr or better with 500ma of stored beam. An in-situ bakeout is required to initially reach a good pressure and to somewhat reduce the photon stimulated gas desorption.

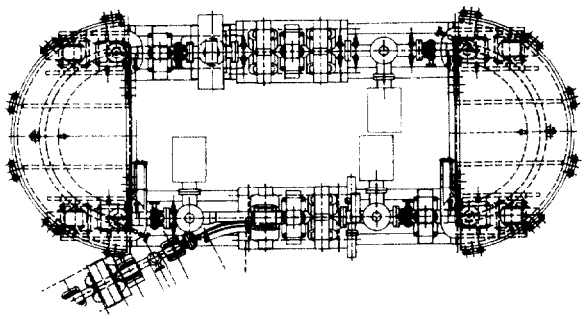

Fig. 1 Plan view of XLS (Phase I)

Chamber Material and Design

INCONEL 625 [1] was chosen for the dipole chamber because of its high strength (Y.S.=60,000 psi), high electrical resistivity (129 microhm-cm), low relative permeability (1.006), and excellent vacuum characteristics [2], [3]. The chamber cross-section is rectangular (30mm x 80mm beam aperture) throughout the dipoles and has a circular (86mm dia) cross-section in the straight sections. Tapered transition sections are used where the round tubes join the rectangular shapes to reduce chamber impedance. Figure 2 is a plan view of a Phase I dipole chamber. It shows the arc chamber assembly with a flag and beam position monitor (BPM), one diagnostic light port and ports for bremsstrahlung observation for ion-trapping tests.

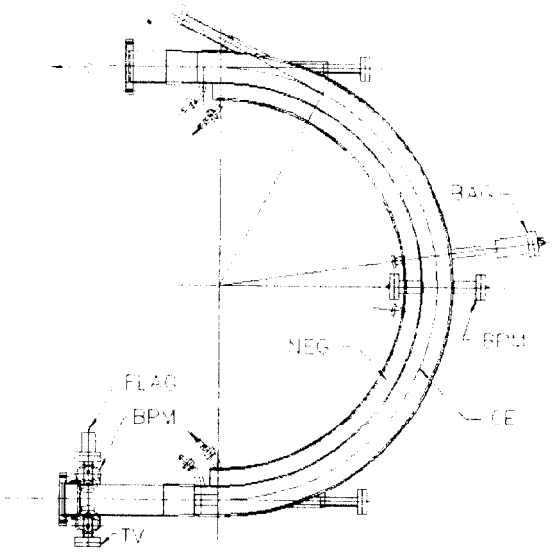

Fig. 2 Plan view of Phase I Dipole Chamber

Figure 3, is a cross section through the dipole chamber showing the clearing electrode and the distributed non-evaporable getter pump (DNEG). Clearing electrodes will be built into all chambers for ion clearing. Bellows are located between the arc chambers at each end of the two straight sections. For 200 MeV and 500 ma operation the power deposited on the chamber walls from synchrotron radiation is 0.3 watts/cm, therefore, no water cooling of the chamber is necessary. However, at 690 MeV the power on the walls in 41 watts/cm which will require cooling.

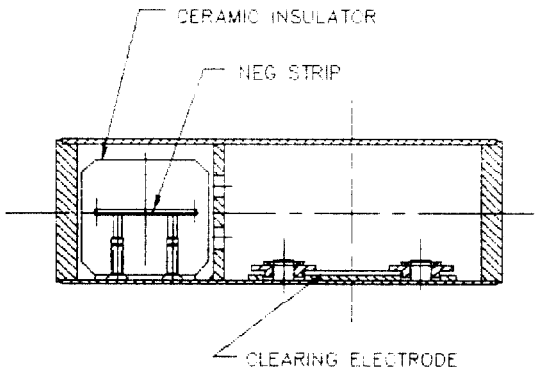

Fig. 3 Dipole Cross Section

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Pumping Requirements

In all synchrotron radiation sources the total gas load Q (Torr liter/sec) comprises two parts, that due to photon stimulated desorption (Q_{sr}) and the other due to thermal desorption (Q_{th}) the dynamic gas load (Q_{sr}) calculated for this machine [4], [5], [6] operating at 200 MeV and 500 ma stored beam will vary from an initial value of 1×10^{-4} Torr liter/sec to 8.4×10^{-7} Torr liter/sec. This variation in gas load is due to a lowering of the desorption yield η (molecules/photon) from "beam conditioning" of the chamber walls. For Phase II operation, 690 MeV and 500 ma, the gas load will vary from 1×10^{-3} Torr liter/sec to 8×10^{-6} Torr liter/sec. The above calculations were based on an initial η of 1.2×10^{-4} molecules/photon [7], [8], and for a conditioned η (150 ampere-hours) of 10^{-6} - 10^{-7} molecules/photon. To these valves must be added the thermal outgassing (Q_{th}) of 2.6×10^{-7} Torr liter/sec, which is based on a specific outgassing rate of 4×10^{-12} Torr liter/sec cm^2 [9].

Pumps

Pumping will be via a combination of pumps. Sputter ion pumps (SIP), titanium sublimation pumps (TSP), and non-evaporable getter pumps (NEG) will be used, thus taking advantage of each pump's optimum operating characteristics. A NEG strip pump will be built into the dipole chamber to provide uniform pumping in this area of high gas desorption and minimum space. In the straight sections and on the rf cavity SIP, TSP and NEG pump assemblies will be used. Considering conductance losses, the total effective pumping speed will be in excess of 5200 liters/sec at 10^{-9} Torr.

Gauging

Ionization gauges will be used for the basic pressure measurements. Thermistor gauges will be used for pumpdown. Quadrupole residual gas analyzers will be used for diagnostics.

Chamber Conditioning and Bakeout

The dipole vacuum chamber material will be vacuum fired for two hours at 900°C prior to fabrication. After machining, all vacuum chamber materials will be vapor degreased, detergent cleaned, lightly acid etched, rinsed in deionized water, and oven dried. Welding of subassemblies will be under a laminar flow hood to minimize dust and particulate matter from settling inside the chamber during assembly. Prior to final assembly in the ring, all vacuum chambers will be glow discharge conditioned first using Ar/10% O_2 and then N_2 to reduce the photon stimulated desorption. The final conditioning will be a 225°C in-situ bakeout.

Phase II

As mentioned earlier, the Phase II machine will incorporate superconducting dipole magnets. The final design is not complete at this time, however, the current thinking is leaning towards a superconducting magnet with a room temperature chamber.

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