Vacuum Processing of 42 GHz, 200 kW CW/Long-pulse Gyrotron

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Abstract: *For reliable operation of high power microwave sources such as high power gyrotron demands stringent vacuum conditions to be fulfilled. In this paper, the vacuum requirements of a 42 GHz, 200 kW CW/ long-pulse gyrotron has been presented and also includes requirement for its heat treatment and vacuum processing.*

Keywords: Gyrotron, Vacuum conditioning, Heat treatment, vacuum processing.

1. Introduction

Gyrotrons are high power microwave sources capable of delivering enormous CW/long pulse power output at few hundreds kWs. They are being employed a variety of plasma heating and other ISM applications [4]. State-of-the-art development of gyrotrons of Thumm gives a globally comprehensive account of the modern day development of such high power sources [1].

A gyrotron operating at 42 GHz and capable of delivering around 200 kW long-pulse output power is being developed for the first time in India for Tokamak applications [3]. This paper deals with the vacuum conditioning requirements [2], [3] and stable operation of such gyrotron. The pressure in the tube should not exceed 10^{-05} Pa under thermal conditions. An appendage vacuum pump is incorporated in the tube for safe operation after pinch off.

2. Fabrication plan

Microwave tube requires low outgassing materials, low base pressures $<10^{-06}$ Pa, brazing techniques, pre-assembly cleaning, vacuum seal selection, jigging and fixtures and handling.

2.1 *Material properties*

Mechanical Properties, being machined and fabricated, must have adequate strength, over the expected temperature range and withstand for vacuum [3, 4].

2.2 *Thermal Properties*

The material's vapor pressure must remain low at the highest temperature. The materials used, are Molybdenum, ceramics, monel/Cu-Ni, OFHC copper, Tungsten and SS-304L. Ceramics should be of high purity.

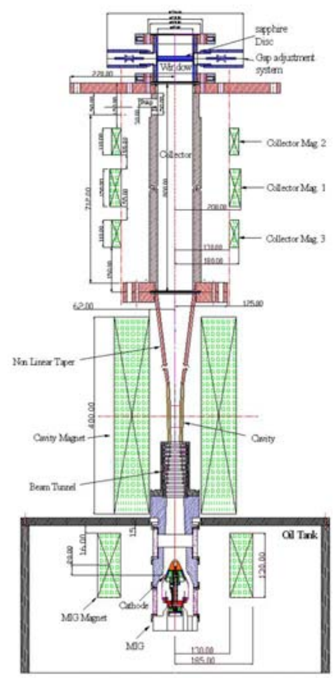

Fig. 1: Schematic diagram of 42 GHz gyrotron with axial output includes layout of magnets and housing.

3. UHV System

The vacuum system has two parts 1) main UHV pumping consists of Turbomolecular pump (TMP) backed by Rotary pump (RP),Ion-pump (IP),UHV Valves, pressure and vacuum gauges,LN_2 trap, RGA, Helium Leak Detector (LD). 2) Rough pumping system for baking beljar system of the tube. The device then goes through a *bake-out* procedure. Baking stations are used to evacuate the tube and bake out any oxygen or other gases from the copper/metal parts of the assembly. It requires extended periods of heating to temperatures from 160° to 450°C. Residual gas analysis measurements of vacuum systems show partial pressures dominated mainly by gases: H_2, O_2, N_2, H_2O, CO, CO_2 and C_nH_m. At base pressures of > $1x10^{-04}$ Pa, more than half of the partial pressure is typically water vapor [2, 4]. Contamination can limit the base pressures attainable in a system. In order to maintain a high vacuum in the gyrotron, the thermal cycles have influence on its life.

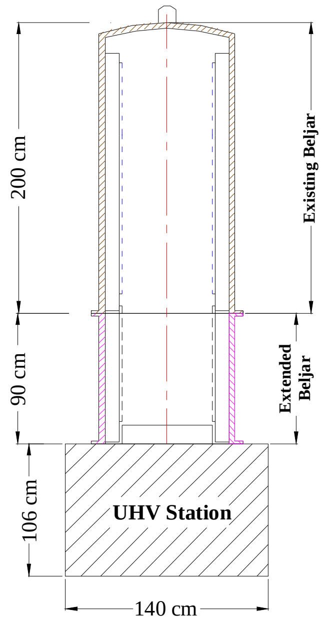

Fig. 2 Schematic layout of vacuum beljar system

4. Vacuum Conditioning Requirements

4.1*Pressure Requirement*

During the heating process, the pressure and the partial pressure of the most common gases measured with RGA to analyze residual gas composition in vacuum system. Better low base pressures $<10^{-06}$ Pa, is desirable for safe operation of the tube.

4.2 *Out gassing Stages and Rates*

The device requires efficient removal of water vapor and various gases, hydrocarbons from the interior walls and surface oxide layers of materials over temperature range.
The outgassing rates of the surfaces have to be at the lower range of 10^{-12} Pa m^3 s^{-1} m^{-2} [2]. Extremely careful handling and extremely careful cleaning and heat treatment of the components and device, are essential.

4.3 *Vacuum Seals*

Conflat flanges (CF) use a copper ring compressed between two knife edges of Pumps, and gauges are joined by flanges, tubes, bellows, and valves, all of which must be vacuum tight, made with low partial pressure materials, and have clean, smooth surfaces. All the parts are either welded or brazed together. After the final heat treatment, the tube is pinched off from the vacuum pumps. Generally, finished tubes do not have demountable seals. Demountable seals are preferable, where an easy exchange of components is desired during the development.

4.4 *Cleaning Procedures*

Simple cleaning procedure for assemblies and components is Ultrasonic wash in hot solvent, rinse with hot pure water and vacuum bake at 250°C. It is necessary to have careful handling and careful cleaning and heat treatment methods employed in the components and devices in order to achieve the most modest levels of vacuum. Finally, the components have to be dried.

4.5 *Leak Detection*

Leak detection is one of the most important aspects of vacuum technology. Important is that the leak rate should be comparatively small and thus does not influence the required working pressure. The most sensitive and reliable leak detectors are mass spectrometer helium leak detectors. The leak rates of 10^{-12} Pa m^3 s^{-1} m^{-2} can be detected and localized. The position of the leak can be found by using a tracer gas.

5. Conclusion

A vacuum requirement for this specific gyrotron has to be maintained at the desired limit so that it will surely address the serious problems arising due to poisoning, ion bombardment, and space charge effects. However, to maintain UHV conditions, special care need to be taken at the time of fabrication which includes right choice of materials, jigging and fixtures, construction procedure, that includes joining and cleaning cycles as well.

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