A 100 MeV LINAC FOR THE SR LIGHT SOURCE

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ABSTRACT

A 4m long linear accelerator has been designed to operate with the energy gain of 100 MeV and the beam current of 100mA, which is scheduled to be installed into the compact synchrotron radiation light source (LUNA) in near future.

In this report, several pre-tests and the design of this linac are discussed. High power test by a 0.5m long test linac shows that it takes 110hr aging to reach no arching condition at the electric field strength of 25MeV/m. And another diffusion bonding test shows that it is possible to make the deformation to be less than 5μm per one cell under optimum conditions of the temperature and the pressure.This designed linac is composed of 5 units, which is made by diffusion bonding method. And each unit is bolted together to form a 4m long linear accelerator. The entire assembly is placed within a cylinder which serves both as a vacuum envelope and as the support structure.

INTRODUCTION

Synchrotron radiation (SR) has potential for industrial use, especially as a light source for x-ray lithography. Ishikawajima-harima Industries (IHI) has developed a prototype compact synchrotron light source named LUNA (lithography use new accelerator). The project was started in April 1987. LUNA was installed at ISRF (IHI Synchrotron Radiation Facility at Thuchiura) in April 1989. Test operations were continued and in December 1989, we succeeded in accelerating the electron beam to the final energy of 800MeV and observed x-ray. In March 1991, the initial target of 50mA beam current and 3hr lifetime was attained. At present, on the one side the machine study and the preparation of x-ray lithography testing are continued and on the other side, the development of the machine which would be put in market is started.

The injector of LUNA is operated at the repetition rate of 1Hz and produces the electron beam which is the energy of 45MeV, the peak current of 100mA and the pulse width of 1μs. The linac consists of an electron gun, a 50cm buncher section, a 1.5m regular section and two 2m regular section. Two S-band klystron with a frequency of 2856MHz are used as rf sources. The accelerator tube is the constant impedance type. The total wavelength of the injector is about 10m. At present, the 4m long new accelerator tube is under development to exchange to 2m regular section, which is designed to increase the beam energy up to 100MeV with keeping the present length of injector and realize the easy operation and maintenance.

HIGH POWER TEST BY 0.5 m ACCELERATOR TUBE

It is important to decide what the accelerating field gradient of a linac is, in order to realize the easy operation and maintenance. If a high accelerating field gradient is adopted, the length of an injector becomes to be shorter, but on the other hand the initial aging time becomes extremely longer and the troubles in operation increase. A careful chemical treatment may be one of the solution to protect an electron discharge, but it is difficult to control the quality of its process. In a design of a linac, it is useful to have estimated an acceptable level of the operating field strength of an accelerator tube without any special treatment on its surface. So rf high gradient experiment of an S-band 0.5m disk loaded structure was done as follows.

The overall organization of the experimental set-up is shown in Figure 1. Rf source is used which is divided from a 22MW TOSHIBA klystron. Rf pulse width used is 1μs at 1Hz rep. The klystron and the 0.5m accelerator tube was connected with WRJ-3 type rectangular waveguide, which is under pressure with SF6 gas at 0.2MN/m^2 to protect discharge. There is a rf window made by ceramics between the waveguide and the input coupler to seal the vacuum of the structure. The rf power in both the forwarde and reflected wave was monitored by some dual Bethe-hole couplers with a coupling ratio of -70dB. The rf power is fed into an accelerating structure and through the power is terminated a rf water load. The structure is pumped through its beam port of the input coupler by 60 l/sec ion pump and the vacuum level is monitored by the current of ion pump.

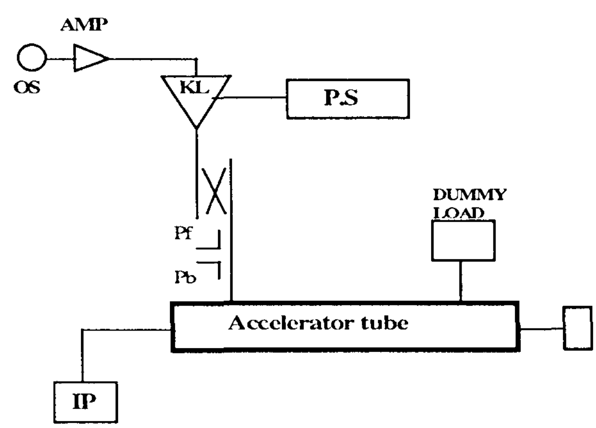

Fig. 1 The experimental set-up

The 0.5m accelerating structure consists of 13 cells regular section, an input and an output coupling cells. The disk and cylinders are machined from OFHC copper blocks with a diamond tool. The final surface roughness is less than 0.04μm without any chemical treatment. Those parts are stacked and combined by the electricforming method. The structure dimensions and low power measured field parameters are summarized in Table 1.

TABLE 1
Parameters of 0.5m test accelarator.

Resonant Frequency	2856MHz
Structure length	63.0 cm
Iris Diameter (2a)	
in	17.757mm
out	14.980mm
Shunt Impedance	68.6MΩ/m
Q	12000
Attenuation	0.49Neper/m
Average group velocity	
(Vg/c)	0.00435

From parameters of the Table 1, the accelerating field E_0 can be estimated in the following way;

$$E_0[MV/m] = 8.27 \sqrt{P_{in}[MW]} \qquad (1)$$

where Pin is the rf input power in MW.

At this experiment, the total aging time gets to be 3310 minutes, and the field strength of 24.5 MV/m at rf power of 9MW is finally attained as shown in Figure 2. A frequency of discharge can be estimated from the change for the worse in vacuum level. Figure 3 shows this frequency of discharge. In this figure the discharge frequency normalized its field strength is put on the axis of ordinates, because the field strength is not constant throughout the experiment.

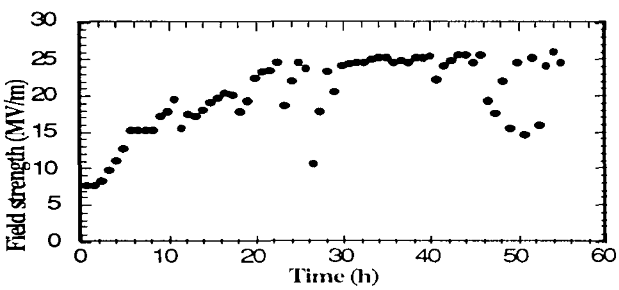

Fig. 2 Relation between aging time and reached field.

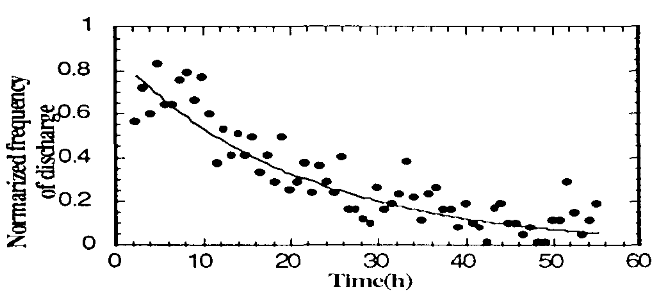

Fig. 3 The character of Aging.

The following experimental formula is got from Figure 3.

$$\frac{P}{E_0} = 0.98 \exp(-0.045T) \qquad (2)$$

where E_0 is accelerating field in MV/m.
T is total aging time in hour.
P is frequency of discharge per 10 minutes.

This formula shows that it takes 110 hr to condition the accelerator structure to be the frequency of discharge of 1 time/10 hr at the field strength of 25 MV/m.

DIFFUSION BONDING

When an accelerator structure is made, more than half of the cost is occupied with the machining cells and the processing of combining cells follows it in cost. Blazing, electroforming, bolting, and shrink fitting have been used to combine cells so far. At present, blazing is most popular among those methods. The cost of the combining process depends on the method and as long as the accelerator structure is, the difference in cost by the methods becomes larger. Recently diffusion bonding method becomes to be widely used in the space and aircraft industries. But a diffusion bonding method has rarely been used to combine cells of accelerator. Since the tolelance of machining cell and the surface of it are usually less than a few micrometer, the surface of cell is directly fit for the diffusion face. In diffusion bonding method, the whole face of the joint is perfectly metallically bound. So it is possible to achieve a good rf contact. But in this method there is a demerit that the creep deformation inevitably occurs in the process of binding. A 30mm length test cell made of OFHC shows the deformation of 5μm by diffusion bonding under optimum conditions of the temperature , its holding time and the pressure. This combined cell shows the tensile strength of 98.0N/mm², the shearing strength of 107.8 N/mm² and the good vacuum seal. Figure 4 shows a cross section of the joint at the enlarged scale 1:100.Figure 5 shows the example of 22 cells and 3 water-cooling plates made of OFHC with two water ways inside, which are combined by diffusion bonding method at the same time.

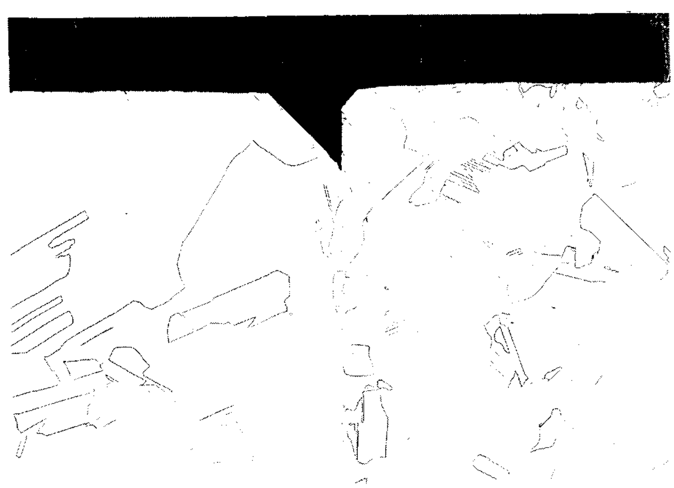

Fig. 4 Cross section of the diffusion bonded cell. (by scale of 100 times)

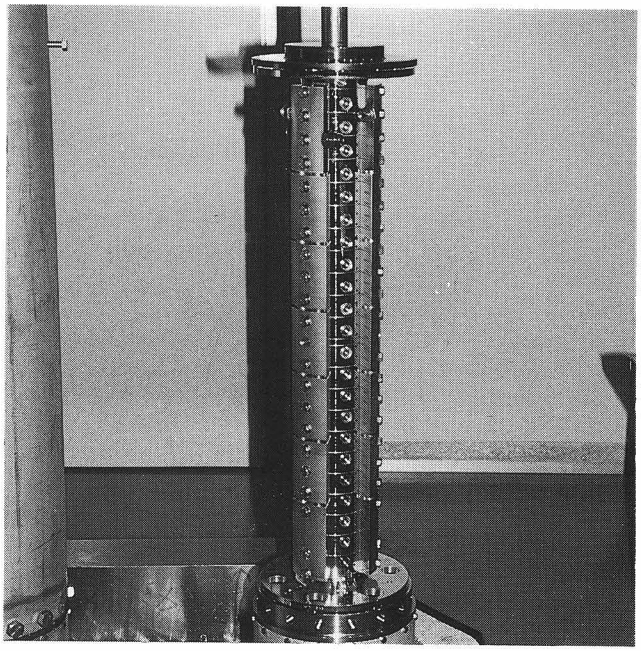

Fig. 5 An example of acceleration structure made by diffusion bonding method.

DESIGN OF THE 4m LONG ACCELERATOR STRUCTURE

The Table 2 shows the final targeted specification of the 4m long accelerator structure. The structure consists of 5 units, 3 units of which are 0.8m long one with 22 cells and the other 2 units have coupling cell and 22 cells. Each unit is combined by diffusion bonding method and bolted together to be 4m long structure. The bolted section is designed to keep good rf contact even if the section would be pressed by external force. Each cell has 8 holes of the diameter of 4mm to improve the vacuum conductance. The entire assembly is placed within a cylinder which serves both as a vacuum envelope and as the support structure. The advantage of surrounding the accelerator structure with a vacuum manifold is that pumping speed at each cell is essentially equal, resulting in a uniform vacuum level throughout the accelerator section.

TABLE 2
Specification of the 4m long accelerator structure

Resonant Frequency	2856MHz
Structure length	3.99m
Q	13500
Shunt Impedance	54.3~62.8MΩ/m
Input rf power	62 MW
Energy gain	107.5MeV
	(100Mev at 100mA)
Filling time	1.32μs
Attenuation	0.88Neper/m

CONCLUSION REMARK

The outcome of this development would be next two points.
(1) Design of the accelerator structure which would be operated and maintained easily .
(2) Establishment of the fabrication of accelerator structure without any restriction of its length.
In our schedule, the fabrication of this 4m long accelerator structure would be finished until October 1992 and low power test of it will be continue.