A 476 MHZ RF SYSTEM FORTHE STORAGE MODE OF THE AmPS RING

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Abstract
The Amsterdam Pulse Stretcher (AmPS) is an electron storage and pulse stretcher ring. The ring operates at energies between 300 and 900 MeV at circulating currents up to 200 mA. A 50 kW RF source with fast amplitude- and phase modulation drives a 2856 MHz accelerator section in the stretcher mode of operation. This RF source doesn't provide enough power to ensure acceptable beam lifetime for storage mode operation at energies above 550 MeV. Therefore a 476 MHz CW RF system has been implemented. Its cavity is a modified, former DORIS (DESY), 500 MHz single cell pillbox cavity. In the cavity a gap voltage of over 400 kV is generated at the maximum 30 kW CW power from a YK1233 Philips klystron. Three RF feedback control circuits are incorporated to stabilize the cavity parameters; one for frequency, the second for the phase and the third for the amplitude. Design, realization and operation of this RF system is described.

I. INTRODUCTION

For the stretcher mode of AmPS a 2856 MHz RF source has been built[1,2]. To obtain reasonable lifetimes in the Storage Mode of operation, a rather high rf voltage will be required at this frequency. At 900 MeV a rf voltage of 700 kV is needed to create a bucket size of $7\sigma_\varepsilon$ (σ_ε being the equilibrium energy spread). The amount of rf power which is needed to generate this voltage in the 12 cavities long travelling wave structure is 1.5 MW CW and not realistic.

At 476 MHz, the sixth subharmonic of the accelerator frequency, only 150 kV is needed to create the same bucket size. For a bucket size of $10\sigma_\varepsilon$, the rf voltage is 270 kV at 476 MHz

For future operation , after 1998, AmPs can be used as a driver for FELINA (Free-Electron Laser in Amsterdam) for the generation of narrow bandwidth radiation in the ultra-violet spectral range ($\lambda \geq 200$ nm). The rf voltage needed for this application at 476 MHz is 350 kV [3].

To fulfill these requirements at a frequency of 476 MHz a new source which have to be realized. The rf related specifications for the present storage mode of operation are:

Energy range	E	[MeV]	300-900
Circulating current	I_b	[mA]	200
Energy spread bucket	δ	[%]	±0.1
Frequency	f	[MHz]	476
Harmonic number	h		336
Compaction factor			0.027
Bending radius magn.	ρ	[m]	3.3
Ring circumference	L	[m]	211.618
Circumference period	T	[μs]	0.7

The rf power requirement is calculated for a bucket size of $10\sigma_\varepsilon$. Table1 shows for the energy range of 500 to 900 MeV and a beam current of 200 mA the effective cavity gap voltage and corresponding rf powerlevels for a single cell reentrant cavity with transit time corrected R_{sh}=4MΩ (V^2/2P) and coupling factor of β=1.6. U_s is the synchrotron radiation loss per turn. U_t is total loss including the parasitic loss. The cavity wall losses for an effective gap voltage of 400 kV are 21 kW.

Table 1

Beam Energy (MeV)	U_s (keV)	U_t (keV)	V_{rf} (kV)	P_{rf} (kW)
500	1.7	2.7	45	0.8
600	3.5	4.5	80	1.8
700	6.5	7.5	125	3.6
800	11.0	12.0	190	7.2
900	17.6	18.6	270	13.4

II. CAVITY MODIFICATION

Modification of the cavity to 476MHz (Fig. 1)

The University of Bonn[5] provided us with a former DORIS (DESY) 500 MHz copper pillbox cavity[4] together with a rf input l oop coupler and plunger system from a 5-cell PETRA (DESY) cavity. The cavity modification steps were as follows,

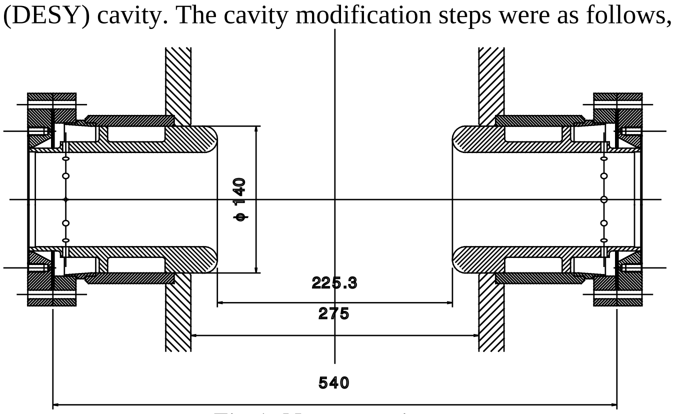

Fig.1 Nose cone inserts

-Calculation by Urmel-T of the cavity RF parameters when it is modified to the operation frequency of 476MHz by the insertion of nose cones. The results are a transit time(T=0.73) corrected R_{sh} of 4.5MΩ (V^2/2P) with a $Q_{unl.}$ of 40000 and R/Q of 112Ω. In the real cavity this impedance is degraded by about 10% due to the addition of ports and the condition of the copper inside surface. The frequency dependency of the nose-cone distance is .62 MHz/mm

-The beamports of the cavity were slightly tapered, they are machined to a final fixed diameter.

-The plunger diameter is machined to a 4 mm smaller diameter to fit the plunger port of the cavity with a 4mm circular spacing. The plunger is water cooled and is tested at 10 Bar waterpressure in vacuum because of the remaining 2mm copper wall thickness with braze joint. The rf input loop coupler was original coupled to a waveguide. In this design it is coupled to a coaxial guide. The diameter of the coaxial window has the EIA 6 1/4" dimensions. To get the cooling pipes of the rf input loop coupler to ground level it was needed to insert a 1/4λ shorting stub of the same dimension coaxial guide into the loop coupler connection with the cooling pipes into the center conductor as shown in fig.2. For the exact coupling range a 4 cm thick adapter is inserted between the cavity and the input loop coupler [6].

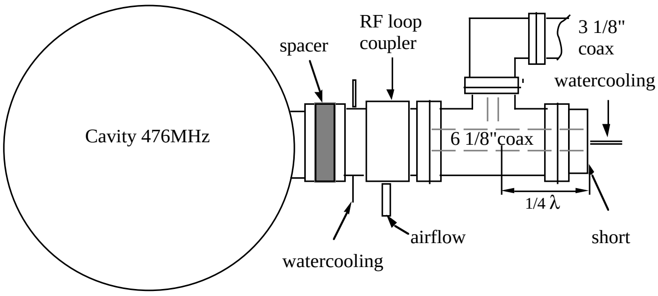

Fig.2 RF input loop coupler

-For the preliminary measurements alumina nose cones are made. In the nose cones there is a groove in which a silver spring is mounted to get good electrical contact for the rf currents.
-Measurement of the actual specs of the cavity while all the components are tuned to the desired specification. Plunger at +7.5 mm depth, angle of rotation of the rf inputloop with respect to the beam direction of about 30° at an overcoupled β of 1.6. Nosecone distance tuned to a resonant frequency of 476 MHz taken into account the temperature of the cavity. Frequency dependency of temperature is 8 kHz/°C. The measured $Q_{unl.}$= 36000 and Q_l=13800. The tuning range of the plunger is from 475.4 to 477 MHz for depth of -15 to +25 mm.
-Low temperature braze of the final copper nosecones into the beamports of the cavity with all the other elements removed.

Vacuum and RF conditioning

The copper cavity had been stored in open air for many years. The inside surface was totaly black. The first action was cleaning of the inside surface by polishing and not etching solvents. The low temperature silver-tin braze of the copper nosecones is done under vacuum at 220°C. After assembling of the cavity with all its accessories it is baked to 100°C for two weeks connected to a 180l turbopump set with mass-spectrometer. The end pressure was 3.1 10^{-9}Torr and the partial pressure content of the carbon-hydrogens was .35% and the cavity ready for installation in the Ring. The rf power test of the cavity is combined with the rf- and vacuum conditioning. For this activity the cavity was still on its position in the ring but isolated from the ring vacuum with a seperate turbo molcular pump and mass-spectrometer. It take two weeks till it was possible to handle 25 kW of CW rf power in the cavity without the appearance of incidental gas bursts. Multipactoring was observed in the peakpower range of .5 to 1 kWatt especially during the very beginning of the rf conditioning.

III. RF SOURCE DETAILS (fig. 3)

Synchronozation

The 476 MHz signal is delivered either by a local synthesizer or by the 6th subharmonic masteroscillator of the MEA accelerator and can be chosen by remote control. When synchronization to the accelerator bunch structure is important for injection purposes the exact phase for optimum capture can be set with phase shifter ps-1.

RF drive details

-PIN switch which is used for protection purposes. If there is an arc in the klystron cavities or in the ciculator or the rf power reflection from the circulator exceeds 4%(VSWR=1.5) the rf power will be switched off to protect the klystron.
-Electronic variable attenuator att-2 of 20 dB as the control device for the cavity voltage level control. Att-1 is used for the adjustment of this control loop.
-Electronic variable phaseshifter ps-3 of 0-360° as the control device for the cavity voltage phase control.. Ps-2 is used for the adjustment of this phase control loop.
-Solid state power amplifier of 50dB to deliver the 50W maximum drive power for the klystron power amplifier.

30 kW power amplifier

The klystron is a Philips YK 1233A normally used for a TV transmitter in the range of 470 to 860 MHz. Philips has tested this klystron at 476 MHz CW operation condition of 29.3 kW. In table 3 the typical specs are given for two levels of operation. Recommanded CW operation is at max. 90% of the saturated output power. This tube has two control electrodes.
-Modulation anode which is powered to 75% of the DC beam voltage to give the desired perveance.
-U_{abc} which is close to the cathode and can be varied from 0 to -1000V to change the gain of the tube by means of DC beam current variation.

Table 3. YK 1233A specifications (typical)

Pout 90% sat.	kW	15	25
Beam voltage	kV	17	20.5
Beam current	A	2.2	2.9
Pdrive sat.	W	6.5	6.5
Bandwidth(-3dB)	MHz	5	5
efficiency	%	45	42

High power coaxial transmission line

The coaxial line close to the cavity and the klystron which contains the directional couplers are of the standard 3 1/8" EIA. For the coaxial waveguide connections between the klystron, circulator and cavity the 100mm diam. fast mounting system(SMS) coaxial guide of Spinner is used because it is easy to install. The circulator is a commercial type from ANT Bosch and can handle the full reflection of 30 kW. The isolation is more than 40 dB and it is stabilized for the change in power level and temperature of the cooling water.

RF control loops

The rf source has three control loops. The electronics of all three systems are in the transmitter area. For this reason two 15m long phase stable 7/8" Flexwell cables are used for the transmission of the the cavity- input and measurement loop signal from the ring vault to the transmitter room.

-The first loop controls the frequency of the cavity under the change of temperature and beamloading. A phase change will be compensated by adjusting the tuning plunger by means of a stepper motor. The response time is in the 0.1sec. order.

-The second loop controls the phase of the cavity voltage. The phase reference is the master oscillator. Any phase change introduced by a temperature change of the coaxial network or a change of the klystron's electrical length or beamloading will be corrected for by the electronic phase shifter.

-The third loop stabilizes the cavity voltage. The rectified output signal from the cavity measurement loop is compared with an adjustable reference level. Any change introduced by the amplifiers or beam will be adjusted for. By changing the reference level the operational cavity voltage can be set. The response time for the last two controls is in the 0.1 msec order.

Higher order modes (HOM)

No effort has been put into the damping of the higher order modes. The maximum beam current level in the ring is 200mA and seems to be just below the level where problems with bunch instabilities will occur. During the operation of the ring in stretcher mode at 2856 MHz problems are observed during the optimization of the extracted current influenced by the 476 MHz cavity in the ring. This effect totally disappeared by detuning the cavity about 0.5 MHz with the plunger..

Operation results

The first experments in the internal target hall with the ring in storage mode at 476 MHz were during Dec/Jan '94/95. The lifetime T of the beam was in the order of 1/2 hour. The max. injected peak current was 50 mA for 3-turn injection which means a circulating current of 150mA. During this period the 476MHz station was started up and operates for 2 month without interruption. The accelerator was in operation at its lowest repetition rate of 10pps. Storage mode experiments are preferently planned in winter time to reduce the electricity costs.

IV. ACKNOWLEDGEMENTS

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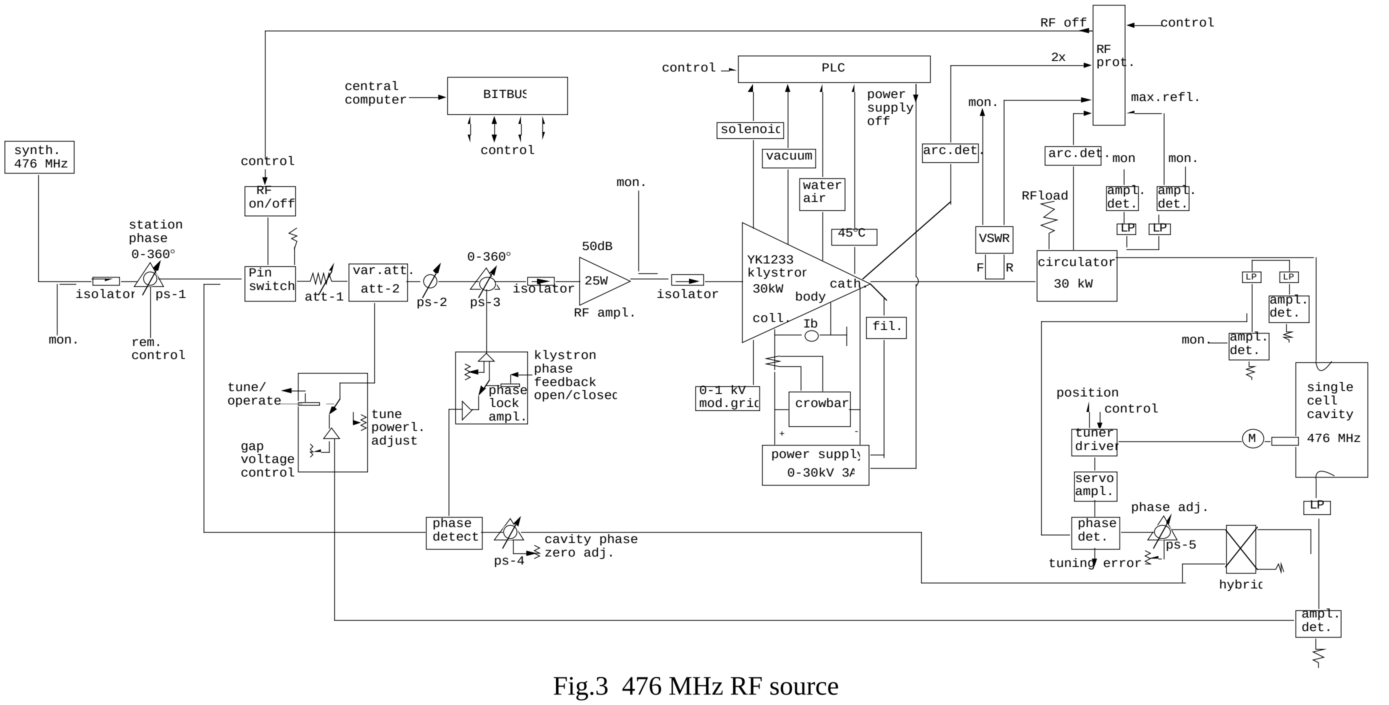

Fig.3 476 MHz RF source