RECONSTRUCTION OF THE 75 MEV LINAC OF THE DELTA SYNCHROTRON-RADIATION-FACILITY

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Abstract

After 4.5 years of operation an extensive reconstruction of the 75 MeV injector linac for the full energy booster of the 1.5 GeV synchrotron radiation (SR) source DELTA was unavoidable. The existing linac, mainly consisting of a 3.8 MeV standing wave buncher and two 4.2 m S-band travelling wave accelerating sections, was fed by two Thomson TH2042E klystrons (25 MW pulse power, two output windows) which are no longer produced and maintained. Therefore we decided to change the RF-system to the new Thomson klystron TH2100 (37 MW pulse power, one output window). At that time we had the possibility to get a 6 m S-band accelerating structure from the decommissioned SBTF at DESY enabling us to replace the two old sections by the new one and to fed this section together with the buncher by a single TH2100 klystron only. This led to a simpler and more reliable system with simplified maintenance.

The paper gives an overview of the new linac assembly, including diagnostics and experimental results. Emphasis will be given to the design and performance of an in house built S-band power divider in R32 3db-hybrid technology which allows for a flexible powering of the buncher and the accelerating section.

1 OVERVIEW OF OLD LINAC SYSTEM

The construction of the S-band linac injector for the 1.5 GeV SR-source DELTA started in 1993 followed by routine operation in summer 1995. Two 4 m sections and the main part of the modulators, power supplies and RF-systems had been taken from the old nuclear physics machine at the university of Mainz/Germany. The system had been completed using a single-cell prebuncher, a 8-cell 3.8 MeV standing wave buncher section and a 50 keV gun for single pulse (2 ns) and long pulse (20 ns) operation [1].

At that time the overall beam performance of the linac did not reach the design values necessary for fast filling of the storage ring with our 0.2 Hz full energy booster. 20% overall transmission had been obtained at 78 MeV with 90 mA peak current (0.18 nC/2 ns) within a rather large $\Delta E/E$ of +/- 2% [2].

From 1995-1999 the operation was determined by difficulties with the RF-system (undefined performance of the used TH2042E klystrons, problems with the two-RF-window operation, lack of RF-power in the buncher section) and by the unstable high voltage power supplies (HVPS) and an insufficient performance of the section cooling. One single klystron had been repaired at Thomson CSF in 1995 and since then all klystrons were used up. In 1996 the decision was taken to change the RF-system to the new one-window TH2100 type, which in addition needs new focusing and housing. In the summer shutdown 1999 the complete system was reconstructed including the implementation of one 6 m travelling wave section from the decommissioned S-Band-Test-Facility (SBTF) at DESY to replace the two existing ones. Initially it was planned to use the two old Mainz sections with two new independent RF-systems. In fact a 75 MeV solution with one section and one RF-system only turned out to be an effective way to meet the requirements for booster injection.

2 LAYOUT OF NEW SYSTEM

2.1 Mechanical Layout

The schematic layout of the new system is given in figure 1. The new 6 m section replaces the two old Mainz sections and the quadrupole triplett (see [1]). The more compact geometry allowed for the installation of additional quadrupoles in the transfer line to ensure a better matching to the booster and additional monitoring.

2.2 Linac Structures

The new installed linac section was part of the DESY SBTF and represents state-of-the-art S-band linac technology [3,4,5]. The main parameters are summarized in table 1. Splitting of the RF-power in vacuum is used to achieve symmetric coupling to the first linac cell. The output power is absorbed in an integrated load (last 8 cells with damping material on iris discs).

The longitudinal pulse compression system consisting of a prebuncher-buncher system has not been changed. For the main parameters of the buncher see table 2.

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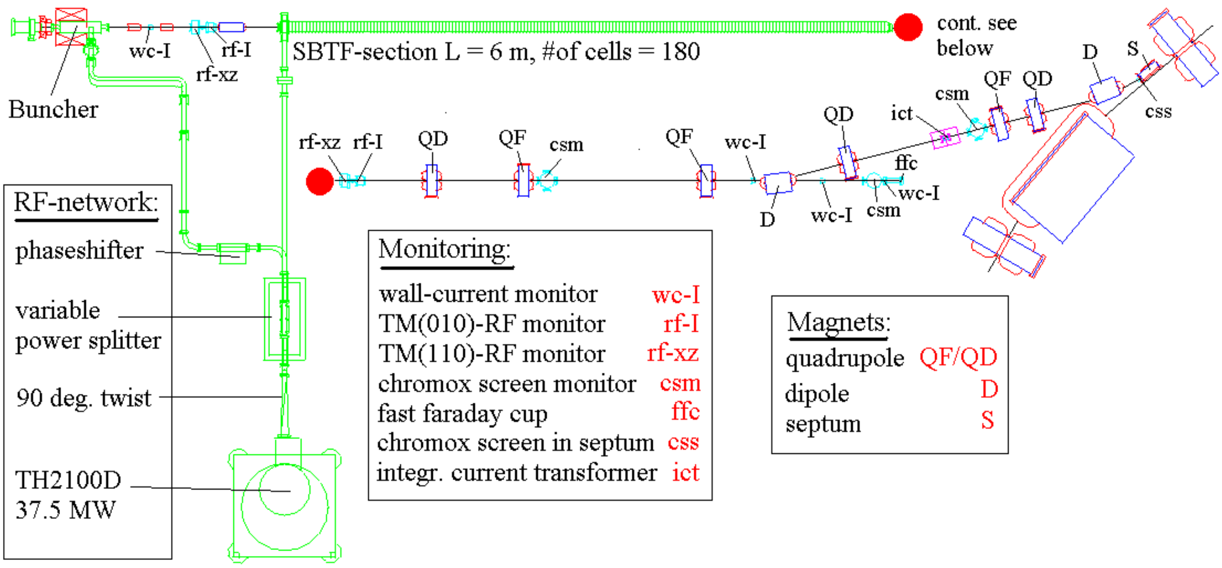


Figure 1: Schematic layout of the new linac system

Very compact water cooling regulation systems have been installed for buncher and section to improve temperature (+/- 0.05^{0}C) and therefore long term energy stability.

Table 1: Parameters of the former SBTF linac section

structure	2π/3 travelling wave, const. grad.
length	6 m
number of cells	179 single cells plus coupling cell
attenuation	0.55 neper
shuntimpedance	55 MΩ/m
filling time	0.79 µs
group velocity	4.1% – 1.3% light velocity

Table 2: Parameters of buncher section

structure	on-axis-coupled, 2π/3-mode standing wave
length, # of cells	0.45 m, 6 cells plus 2 endcells
ß-profile	ß = 0.92, 0.98, 1.00
energy gain	3.8 MeV @ 2.6 MW
max. E-field on axis	16 MV/m @ 2.6 MW

2.3 Radiofrequency System

Prebuncher, buncher and the SBTF-section are powered via one TH2100 klystron (37.5 MW max. output power). The klystron housing and modulator tank follows a design from LIL/CERN and was built with slight modifications (especially the movers for precise positioning and assembling of the klystron) from the Forschungszentrum Jülich. The old PFN-system is still in use, the old HVPS has been replaced by a compact state-of-the-art Maxwell power supply (CCDS, 32 kV, max. 10kJ/s). The manufacturer guarantees a voltage stability of +/- 0.05% leading to a HVPS related energy stability of $\Delta E/E$ = +/- 0.063% (see section 3).

Power splitting between section and buncher is done via a variable power divider.

During the summer shutdown 1999 the complete control of the RF-system has been altered and completed for improved handling and additional interlock functions. Based on a SIEMENS P7 the complete system can now be set into operation in a remote way and a first fault detection was integrated.

2.4 R32 3dB-Hybrid-Power-Divider

An in house built power divider in R32 hybrid technology, consisting of two 3 dB hybrids for power splitting and combination and one 3 dB hybrid acting with two sliding shorts as a phase shifter, gives the opportunity to power the buncher individually from a given RF-setting for the main accelerating section (see fig. 2).

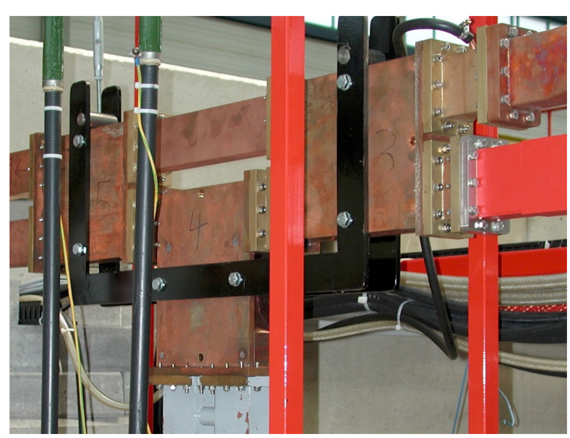
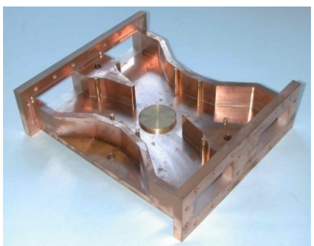


Fig. 2: R32 variable power divider consisting of three 3dB coupler and two sliding shorts (lower part).

Layout (optimization of the couplers (see fig. 3) with respect to power ratio and S-parameters) and low power as well as high power tests have been done at DELTA [6], manufacturing and soldering partly at ACCEL/Bergisch-Gladbach.

Special attention has been given to the realization of the sliding shorts for high power operation. Contacts to the waveguide have to be avoided absolutely at regions of high field level. The chosen setup is shown in fig. 4. The geometry of the cylinders have been fully optimized with respect to minimum field level at the rear plane position.



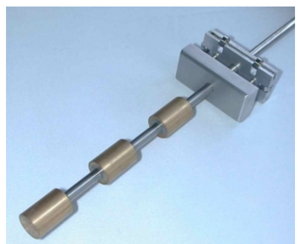


Figure 3 (left): 3 dB coupler layout prior soldering
Figure 4 (right): Layout of sliding short

This variable power divider is able to operate at 2.5bar SF_6 under the full input power of 37MW. During the commissioning of the RF distribution system the power divider has been tested in a range from 37MW/0MW up to 27MW/10MW. The reflected power at the input port is well below –21dB over the full operating regime and below –27 dB at the operating point.

2.5 Transferline Linac-Booster

The use of only one linac section made a redesign of the transferline between linac and booster possible (see fig. 1). With the implementation of two additional (now six) quadrupoles a complete matching of the optical functions including dispersion is possible with respect to the input data of the booster. The optical layout allows minimum ß-functions ($ß_x$= 0.3m, $ß_z$= 2m) at a reasonable dispersion of 0.48m at the location of a screen monitor in front of quadrupole no. 5.

2.6 Linac Monitoring

The monitoring system has undergone major alterations and supplementations (see fig. 1). Three screen monitors are now available, two in straight direction and one at a region of dispersion mainly for measurements of energy spread and beam stability. For precise bunch charge measurements prior injection an integrated current transformer had been added. The time structure can be obtained from wall current monitors.

3 PERFORMANCE OF NEW SYSTEM

First beam with the new system was obtained in October 1999. After now 6 months the experience with the system is excellent concerning operation, maintenance and stability. Full RF-performance has been reached and the existence of only one transmitter eases handling in daily operation. The enhanced stability of the HVPS and the water cooling system gave rise to a very low energy spread well below the acceptance of the booster (+/-0.5%). The present performance for single bunch operation is summarized in table 3. In the case of multibunch operation we obtain slighty less output current and clearly see the increasing beam loading. The output charge per bunch is still limited (20% overall transmission) by transverse focusing restrictions in the low energy part. Since numerical simulations are in good agreement with measurements we now can clearly identify the obstacles with respect to higher bunch currents followed by alterations in 2001/2002.

Table 3: Present performance of new linac system for single bunch (2ns) operation

nom. input/output energy	50 keV -75 MeV
beam pulse structure	2 – 90 ns
output bunch charge	0.36 nC in 2ns beam pulse
output beam current	180mA in 2ns beam pulse
energy spread ΔE/E	+/- 0.21% full width
beam loading	appr. 0.1% in 2ns
absolut output emittance	< 0.8 π mm mrad (100%)

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REFERENCES

[1] G. Blokesch et al., “The Injector Linac of the DELTA-Facility”, Proceedings EPAC´96, Sitges, June 1996

[2] A. Jankowiak et al., “Present and Future Performance of the DELTA Injector Linac”, Proceedings 1996 Linear Acc. Conf., Geneva, August 1996

[3] R. Brinkmann et al., “Conceptual Design of a 500 GeV Linear Collider with Integrated X-Ray Laser Facility”, DESY-Report 1997-048 (1997) 591ff

[4] M. Schmitz et al., “The S-Band Linear Collider Test Facility”, Proc. 1997 Part. Acc. Conf. (1997) 569

[5] N. Holtkamp, “The S-Band Linear Collider Test Facility”, Proc. EPAC´96, Sitges, June 1996

[6] H.Bendfeldt Hoppe, “Entwicklung und Bau eines variablen Hochleistungsteilers unter Verwendung von R32-Hybridtechnologie”, diploma thesis (1998), Dortmund university