RECENT RESULTS FROM THE X-BAND PULSED MAGNICON AMPLIFIER*

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Abstract

A frequency-doubling magnicon amplifier at 11.4 GHz has been designed and built as an alternative microwave source for testing high power RF components and accelerating structures. The tube is designed to produce ~60 MW, ~1.2 microsecond pulses at 58% efficiency and 59 dB gain, using a 470 kV, 220 A, 2 mm-diameter beam. In the first tests the output power was limited to a level of 26 MW in a 200 nsec pulse. This limitation was believed to be caused by oscillations in the collector. Preliminary experimental results of magnicon tests with a new collector are presented in this paper.

INTRODUCTION

This paper describes the current experimental status of the 11.424 GHz Omega-P/NRL magnicon amplifier [1], that is under development as an alternative RF source for a future electron-positron linear collider. The magnicon [2] is microwave amplifier tube that combines the scanning beam synchronism of the gyrocon [3] with a cyclotron resonant interaction in the output cavity. This synchronism makes possible high efficiencies and, with larger cavities than in klystrons, allows higher powers at high frequencies than comparable klystrons [2,4].

A schematic layout of the Omega-P/NRL magnicon is shown in Fig. 1. The tube consists of an electron gun, a ~6.5 kG solenoid magnet, an RF circuit, and a beam collector insulated from ground. The 500 kV diode gun provides the required 100 MW of beam power, producing a 2 mm diameter beam in the solenoid which corresponds to a beam area compression of 1400:1 [5]. The RF circuit has six 5.712 GHz TM_{110} deflection cavities (a drive cavity, three gain cavities and two penultimate cavities), followed by an 11.424 GHz TM_{210} output cavity. In contrast to the magnicon described in ref. [4], the two penultimate cavities are not coupled and operate in the angle summing mode, in order to suppress an instability that limits the pulse width [6]. To extract RF power there are two output apertures at the downstream end of the output cavity, separated by 135°, that couple to WR-90 waveguides.

The magnicon design parameters for the measured 2-mm beam diameter [5] are summarized in Table 1. A general view of the tube is shown in Fig.2.

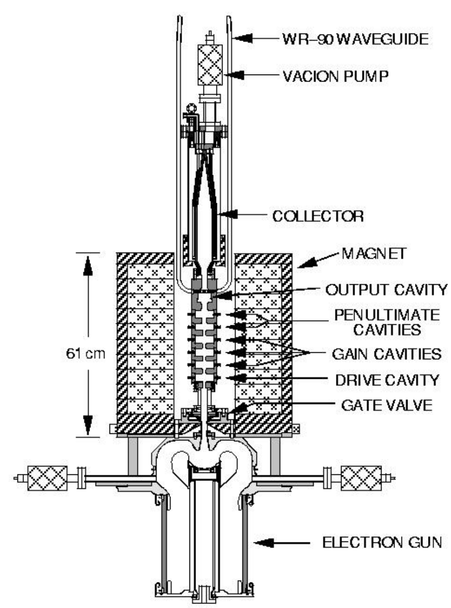

Figure 1: The magnicon schematic.

Table 1: Design parameters of the X-band magnicon.

Frequency, GHz	11.424
Power, MW	60
Efficiency, %	58
Pulse duration, μsec	1
Maximum repetition rate, Hz	10
Gain, dB	59
Drive frequency, GHz	5.712
Beam voltage, kV	470
Beam current, A	220
Perveance, A-$V^{-3/2}\times10^{-6}$	0.68
Beam diameter in magnet, mm	2

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EXPERIMENTAL RESULTS

1. Operation of the Omega-P/NRL magnicon has established an 11.424 GHz high power accelerator test facility at NRL. Since 2001, the facility has been used to carry out two separate collaborative experimental programs, namely study of high-power active microwave

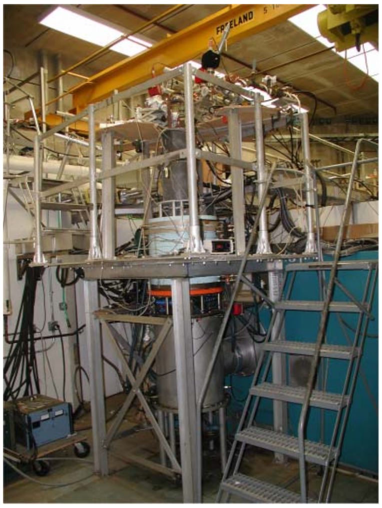

Figure 2: General view of 11.424 GHz magnicon.

pulse compressors and high-gradient dielectric-loaded accelerating structures [7]. In 2002 high-power ceramic windows were installed at the magnicon output waveguides. These windows, manufactured by Calabazas Creek Research, Inc. [8], allow one to change the test experimental configuration without breaking vacuum in the tube. Starting in February 2003, the magnicon underwent an extensive three-month cycle of RF conditioning. After this cycle of conditioning, the output power remained limited to a level of 26 MW in a 200 ns pulse, and 10-12 MW in a 1 microsecond pulse [9]. The output power was measured calorimetrically in both output waveguides. The measurements show that the output powers in the waveguides are equal to within a few percent. The magnicon signals at high power level are shown in Fig. 3. As is seen, pulse shortening in the output cavity occured, but not in cavity #6 or the other deflection cavities.

2. In an attempt to understand the possible cause of the observed output power limitations, measurements of microwave signals from the collector have been made [9]. These measurements showed evidences of excitation of a resonant mode (amplification) in the collector, with efficient interaction of the gyrocon/magnicon type [2,3] at the drive frequency of ~5712 MHz (see collector signal in Fig. 3). Most probably, electrons from multipactoring in the collector drift along the magnetic field into the output cavity, thereby triggering multipactoring therein.

3. The new collector was designed and fabricated, based on the design of the collector built for the 34 GHz Omega-P magnicon [10]. The new collector layout is shown in Fig. 4. A 100 mm long pumping channel with diameter of 15 mm is integrated at the end of the collector. Molybdenum target is placed in the end of the channel (see Fig. 3) in order to detect anomalous current rises due to ion focusing during tube conditioning, so as to protect the collector from possible damage.

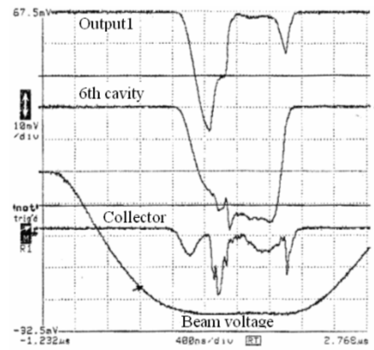

Figure 3: Magnicon signals for high power.

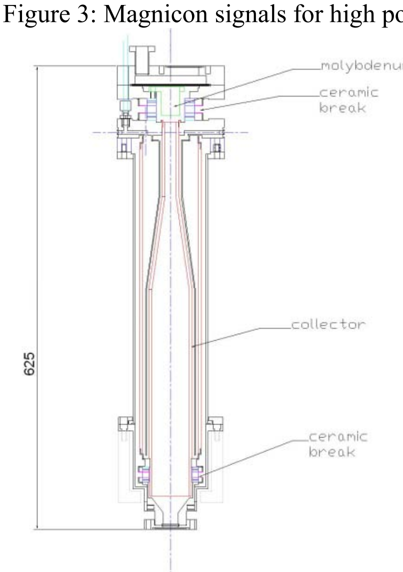

Figure 4: The new collector layout. Dimensions are in mm.

Computed beam trajectories in the collector in the absence of RF drive are shown in Fig. 5. Electron trajectories for normal operating conditions with maximum efficiency are shown in Fig. 6. A photograph of the new collector installed on the magnicon is shown in Fig. 7.

4. The collector was installed on the magnicon just a few weeks before this conference. Initial tests without RF drive indicated an excessive current on the molybdenum target. The most probable cause is an asymmetry in the position of the pole piece attached near the beam entrance of the collector. The excess current was eliminated by using a steering coil, with the target current reduced from ~8 A to ~ 0.4 A, which is lower than design value of ~0.5 A. Oscillograms of beam voltage, collector and gun currents are shown in Fig. 8.

At this writing, RF conditioning is progressing. To date, the maximum output power is >20 MW. Oscillograms of signals for the last gain cavity (#4) and "penultimate" cavities (#5 and #6) are shown in Fig. 9. Output signals are in Fig. 10. At the present power level, output signals do not show evidence of pulse shortening.

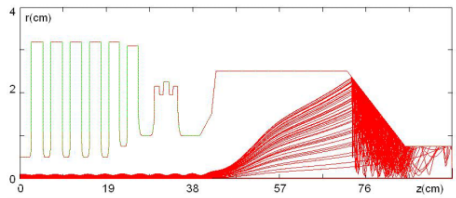

Figure 5: Electron trajectories in the beam collector for condition of zero drive power in the input cavity, including three generations of secondary electrons.

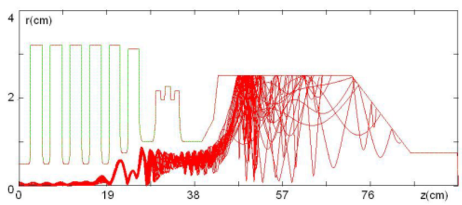

Figure 6: Electron trajectories in the beam collector, for conditions of full RF power operation.

Figure 7: View of the new collector installed on the magnicon, prior to installation of the pole piece.

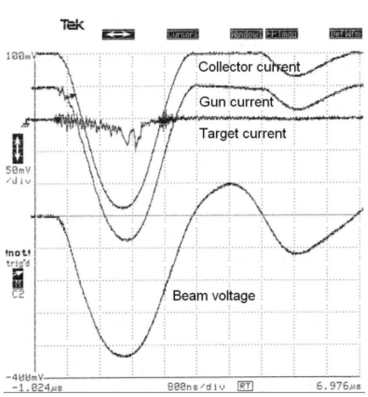

Figure 8. Beam voltage, collector current, gun current and target current.

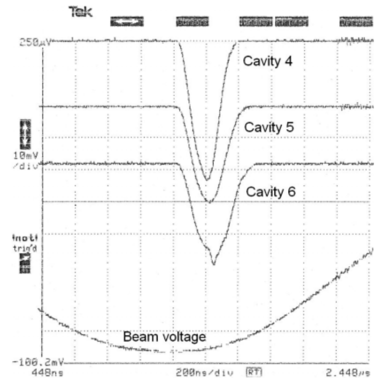

Figure 9: Signals from the last gain cavity (#4) and "penultimate" cavities (#5 and #6).

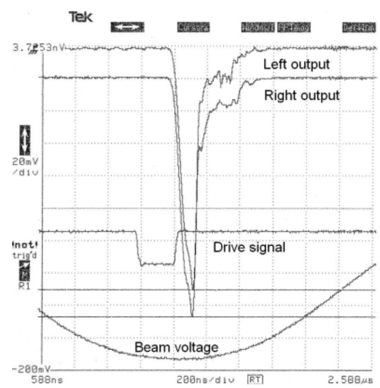

Figure 10: Output signals.

CONCLUSIONS

The new collector has been built and installed, and reconditioning of the magnicon is in progress. After only three weeks of operation, an output power of >20 MW has been achieved in short pulse operation. Near term plans are to continue conditioning, using both short and long pulses, in order to reach the maximum output power.

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