Corrugated Transmission Line Systems for 395 GHz/600 MHz and 460 GHz/700 MHz DNP-NMR Spectroscopy

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Abstract — We present the design, initial installation and test results of two corrugated waveguide transmission line systems for coupling terahertz power from gyrotrons to two different solid-state Dynamic Nuclear Polarization — Nuclear Magnetic Resonance (DNP-NMR) spectrometers at 600 MHz and 700 MHz ($^1$H). The first system combines the power from two different tunable 460 GHz gyrotrons to the DNP-NMR experiment while the second line couples power from a single 395 GHz tunable gyrotron to the DNP-NMR experiment. The lines are currently being installed at the Institute of Protein Research in Osaka University. Test results of individual components and system level test results will be presented.

I. INTRODUCTION

In recent years DNP has attracted considerable interest as a method for increasing sensitivity in NMR experiments [1]. Although the fundamental principle of DNP was discovered several decades ago, it is only during the last decade that rapid advancements have been made possible with the availability of new technologies such as gyrotron oscillators that provide high-power radiation at millimeter wave and terahertz (THz) frequencies [1]. In a DNP experiment, the large polarization of the electron spin reservoir is transferred to the nuclear spin reservoir by irradiation of the electron paramagnetic resonance (EPR) transitions by THz waves. The method is of significant interest in applications ranging from particle physics [2] to structural biology [1, 3] and clinical imaging [4]. Recently reported results show the dramatic potential of DNP in high field solid-state NMR spectroscopy with achieved signal enhancement of $\varepsilon$~47 at 600 MHz [5] and $\varepsilon$~40 [6] in 700 MHz solid-state NMR experiments.

II. RESULTS

At the Institute of Protein Research (IPR) in Osaka University, a 395 GHz/600 MHz ($^1$H) DNP-NMR system based on a tunable 395 GHz gyrotron is currently being used for solid-state NMR studies of biological samples [5]. A novel 460 GHz/700 MHz ($^1$H) is currently under development, which combines terahertz power from two different gyrotrons with frequencies of 460.4 GHz and 460.0 – 461.0 GHz. The first gyrotron will be modulated over a frequency range of ± 100 MHz at a rapid rate (several kHz) while the second gyrotron will be frequency tunable over 1 GHz.

Two different overmoded corrugated waveguide (CWG) transmission line systems are under development for the 395 GHz and the 460 GHz systems. The lines are based on broadband CWG components of 19.1 mm diameter and designed for operation from 350-530 GHz. A brief description of each system is presented below.

\textbf{a) 395 GHz/600 MHz System}

A CWG system has an overall length of~3 m and includes several miterbends, variable power attenuator, power monitoring miterbend, a universal polarizer and a calorimetric load. The system will also include a pair of phase correcting mirrors to optimally inject the gyrotron output into the CWG line.

\textbf{b) 460 GHz/700 MHz System}

The 460 GHz system has two waveguide systems each of which includes the same type of components as the 395 GHz system. In addition, a balanced diplexer system is used to combine the power from the two different lines for final injection into the DNP-NMR experiment. A schematic of the novel power combiner system is shown in Figure 1.

III. SUMMARY

Currently the 460 GHz system is being installed at IPR. We expect to present experimental test results of the individual components and the preliminary tests results of the complete system.

REFERENCES