§24. Development of Advanced Microwave and Millimeter-Wave Devices for LHD Diagnostic Systems

Mase, A. (KASTEC, Kyushu Univ.),
Ito, N. (National Inst. of Tech, Ube College),
Kogi, Y. (Fukuoka Inst. of Tech.),
Kuwahara, D. (Tokyo Univ. of Agriculture & Tech.),
Nagayama, Y., Tokuzawa, T., Tsuchiya, H.

Microwave to millimeter-wave diagnostics have been well developed by the advancement of devices using integrated circuit and micro-fabrication technologies and of computer technologies. Microwave imaging is one of the attractive methods to visualize dynamic behavior of plasma fluctuations [1, 2]. The purpose of this research is to develop components and systems for these diagnostics, and apply to the LHD experiment.

Recently, we have started a study of synthetic imaging as well as of optics imaging. The advantage of synthetic imaging is that the image can be reconstructed without need of large lenses having high optical quality. The synthetic imaging is applied to a remote-sensing, so called, synthetic aperture radar (SAR). Two types of SAR system have been operated as strip-mapping mode and spotlight-mode SARs. In the former type, the processing of the reflected signals allows the effective synthesis of a very large antenna, which provides high resolution. The latter technique is interpreted as a tomographic reconstruction problem.

The resolution of the SAR image, in the range and the azimuth directions, is determined by the bandwidth as well as the carrier wavelength. In conventional microwave SARs the frequency and the bandwidth are assigned by the Administration of Radio under the Ministry of Internal Affairs and Communications in Japan. However, there is no bandwidth limitation in the infrared region. We have developed an ultra-wideband microwave-modulated laser radar which is designed and fabricated for the improvement of spatial resolution both in the range and the azimuth directions [3]. The frequency modulation (1-18 GHz chirp) is applied to an infrared laser source in 1550 nm wavelength. Considering the influence of radiation pattern for microwave antennas case, there is no side lobe in laser beam transmission. Ambiguous signal and interferences which are returned from the ground can be suppressed.

A prototype of laser-radar system with a fiber collimator for transmitting and receiving optics has been constructed as shown in Fig. 1. The transmitter unit contains both optics and control electronics. The wave is amplified by a fiber amplifier and irradiated by a transmitting optics (a beam expander with a fiber collimator). The reflected wave is picked up by a receiving optics and injected to a receiving unit via a fiber amplifier. A tunable filters with bandwidth of 1 nm is inserted between amplifiers in order to improve the signal to noise ratio (SNR).

A vector network analyzer is used to obtain S_{21} signal between the microwave modulation input and that of received signal. The system is applied to the measurement of the distance (position) of an object. It is proved that the spatial resolution is ~ 1 mm during 5-20 m. As an initial experiment, we have succeeded to obtain 3D image of object by scanning a laser beam in two dimensions as shown in Fig. 2 [4]. In order for the spotlight-mode operation, the direction of the incident beam is controlled by a gimbal rotor unit or a fast scanning optics.

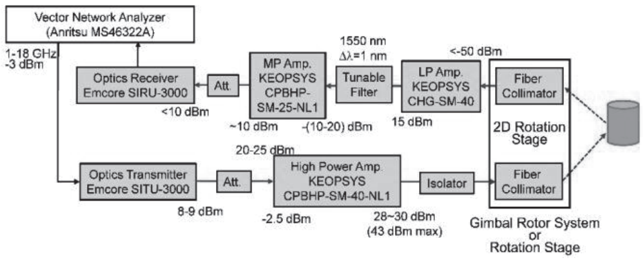

Fig. 1. Schematic of synthetic imaging system using microwave-modulated infrared laser.

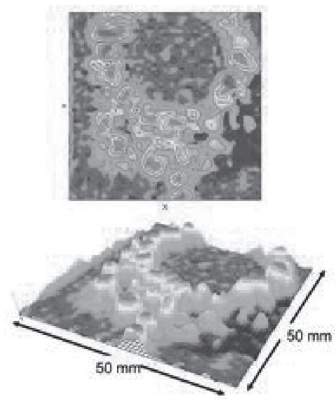

Fig. 2. An example of laser imaging.

In conclusion, we have developed an ultra-wideband (1-18 GHz) microwave-modulated laser radar (1550 nm wavelength), which is designed and fabricated for the improvement of spatial resolution both in the range and the azimuth directions. The application of the system to plasma diagnostics (such as diverter plasmas) is being investigated.

[1] Kuwahara, D., Ito, N., Nagayama, Y., Kogi, Y., Mase, A et al., Rev. Sci. Instrum. 85 (2014) 11D805.
[2] Yun, G. S. et al., Rev. Sci. Instrum. 85 (2014) 11D820.
[3] Wang, X., Mase, A. et al., J. Electromag. Waves Appli. 28 (2014) 917904.
[4] Mase, A. et al., Proc. SPIE: Optical Engineering and Applications, San Diego (Sep. 2016) (to be published).