Fourier transform spectroscopy using a femtosecond laser with high resolution and broadband spectrum for remote sensing application

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Discrimination of chemical substances in the field of remote sensing with high resolution in real-time is recently getting significant. So we present experimentally that Fourier transform spectroscopy using femtosecond laser can realize broadband spectroscopy with high resolution for remote sensing application. Spectrum of light source achieving from the spectrometer has about 7 THz bandwidth at 1560 nm wavelength region. The resulting resolution corresponds to 2 GHz, which is successfully verified by obtaining the source spectrum of the laser.

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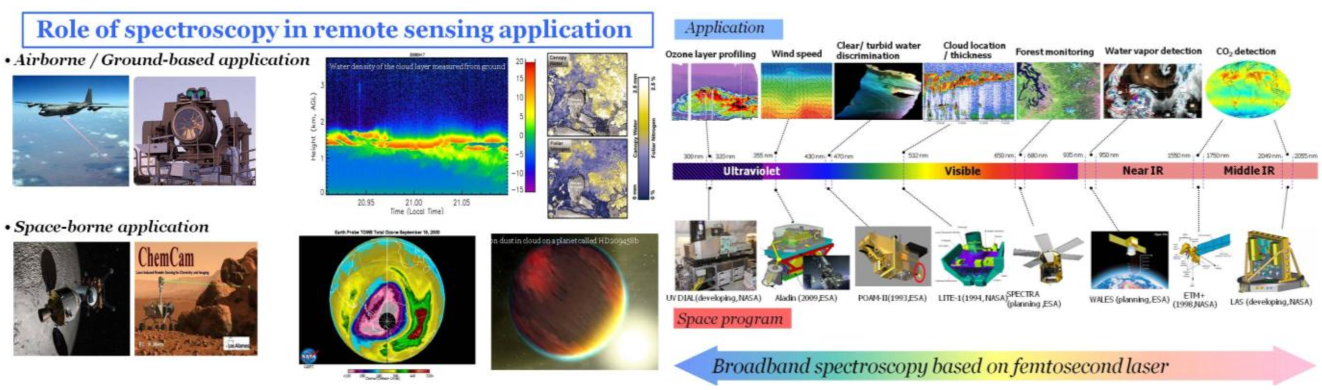
1. Introduction

In the field of remote sensing, identification and discrimination of chemical substances or molecular fingerprints with high resolution in real-time is recently getting significant. Indeed, to detect abundant of absorption lines, broad bandwidth of light source is essential. To satisfy the requirement, various kinds of spectroscopic principles have been proposed and demonstrated. One of those principles is Fourier transform spectroscopy (FTS) which has been widely used as a powerful analytical method for a broadband spectroscopy in the field of remote sensing, from ground-based to space-borne applications. In case of conventional FTS, however, wide-range mechanical scanning with careful displacement monitoring is required to achieve a sufficient resolution with expense of the measurement speed. Here, to overcome the limitation of conventional FTS, we report the non-mechanical scanning based FTS using a femtosecond laser with frequency tuning. Furthermore, the femtosecond laser offers broadband spectrum by the supercontinuum generation. Fig. 1 (a) shows the role of spectroscopy frequently utilized recently in remote sensing. And fig. 1 (b) indicates the various kinds of molecular fingerprint from IR to UV range measurable simultaneously using broadband femtosecond laser.



(a) (b)

Fig. 1 (a) Role of spectroscopy in remote sensing application, particularly in airborne and space-borne application.
(b) Atmospheric quantities measurable from broadband spectroscopy using femtosecond laser and corresponding space missions.

2. Experimental system configuration and result

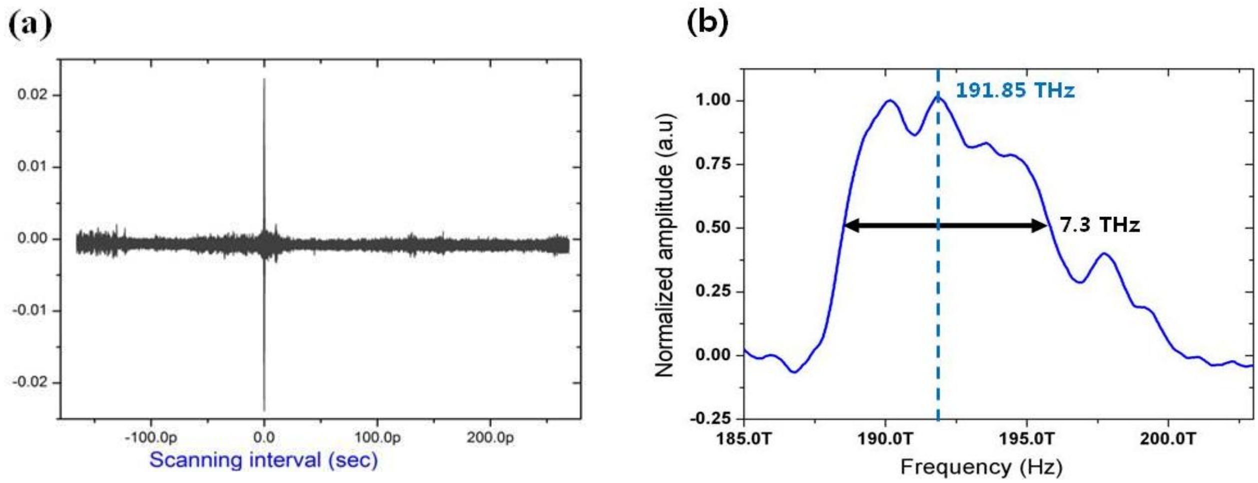


Fig. 2 (a) Interference signal by carful scanning of reference pulse of FTS system. (b) Spectrum of the femtosecond laser .

Fig. 2 (a), (b) shows a experimental result of femtosecond laser based FTS system. The pulse train of reference arm is scanned carefully by monitoring pulse repetition rate of femtosecond laser. At the detection part reference and measurement pulse are overlapped results interference fringe which denotes autocorrelation signal of the light source. In Fig 2(b), experimental result shows the spectrum femtosecond laser source by Fourier-transform of interference signal. By careful monitoring of repetition rate of the femtosecond laser, precise and wide-range of pulse scanning is enabled. We achieved the source spectrum of the femtosecond laser with about 7 THz bandwidth and 1560 nm center wavelength. The resulting resolution of the spectrometer is 2 GHz, equivalent to 150 mm scanning distance in conventional FTS.

3. Conclusions

We investigated Fourier transform spectroscopy using femtosecond laser as the broadband light source for broad bandwidth spectroscopy and verified the capability for remote sensing application theoretically and experimentally. From the experiment, we achieved IR spectrum of the light source covering 60 nm bandwidth at 1560 wavelength region with 2 GHz resolution. This result means that by using this spectrometer, we can resolve the various kind of molecular fingerprints between 1530 nm and 1590 nm simultaneously, and can expand the spectral bandwidth from UV(400 nm) to IR(1600 nm) by generating nonlinear effect, such as super continuum of the femtosecond laser.

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REFERENCES

1. R. C. Olsen, “Remote Sensing from air and Space.” SPIE, 2007
2. M. J. Persky, “A review of spaceborne infrared Fourier transform spectrometers for remote sensing.” Rev. Sci. Instrum. 66(10), 1995
3. Fujii, Fukuchi, “Laser Remote Sensing.” CRC Press, Tayler & Francis, 2005
4. J. Mandon, G. Guelachvili, “Fourier transform spectroscopy with a laser frequency comb.” Nature photonics vol 3, 2009
5. S. A. Diddams, L. Hollberg, “Molecular fingerprinting with the resolved modes of a femtosecond laser frequency comb.” Nature vol 445, 2007
6. S. Schiller, “Spectrometry with frequency combs.” Optics letters, Vol. 27, 9(2002)
7. I. Coddington, C. Swann, “Coherent Multiheterodyne Spectroscopy using Stabilized optical Frequency Combs.” PRL 100, 013902(2008)
8. F. Keilmann, R. Holzwarth, “Time-domain mid-infrared frequency-comb spectrometer.” Optics letter vol. 29, 2004
9. F. Keilmann, “Frequency-comb infrared spectrometer for rapid, remote chemical sensing.” Optics Express vol. 13, 9029(2005)
10. Jun Ye, “Absolute measurement of a long, arbitrary distance to less than an optical fringe.” Optics letter vol. 29, 2004
11. D. M. brown, K. Shi, “Long-path supercontinuum absorption spectroscopy for measurement of atmospheric constituents.” Optics express vol. 16, 8457(2008)