ACOUSTO-OPTIC RADIOSPRECTROMETERS FOR MM-WAVE SPECTROSCOPY

Yoshihiro Chikada[1], Nobuharu Ukita[1], Junji Inatani[1],
Norio Kaifu[2], and Shinji Kodaira[3]
[1]Department of Astronomy, University of Tokyo
[2]Tokyo Astronomical Observatory
[3]Kisarazu Technical College

In mm-wave spectroscopy, the acousto-optic spectrometer (AOS hereafter) compares favourably with conventional spectrometers such as filterbanks or autocorrelators. Although its frequency resolution is limited to 20 kHz and its instantaneous bandwidth is limited to several hundred MHz, it has 10^3 resolvable points. Because of the simplicity and stability of the AOS, it is not difficult to construct and maintain a system of 10^4 resolvable points by the parallel operation of spectrometers. At Tokyo Astronomical Observatory (TAO) a new AOS has been constructed which is equipped with two different types of TeO_2 AO deflectors and provides high resolution (38 kHz) or wide band (220 MHz) spectra. It has 1728 frequency channels (figure 1). Another AOS has been built at Kisarazu Technical College (KTC) for a CO survey at 115 GHz. It has 256 frequency channels and a bandwidth of 230 MHz (figure 2).

The principle of the operation is simple. It was first described by Lambert (1962). The intermediate frequency signal from the receiver is fed to a piezo-electric transducer ($LiNbO_3$) bonded on AO material (TeO_2) and is converted to an ultrasonic wave. The wave travels through the material, maintaining the spectral information of the radio frequency signal. A He-Ne laser beam is diffracted by the ultrasonic wave and is focused on an image-sensor to produce a spectral image. The detected light intensity as a function of diffraction angle is proportional to the radio-wave power as a function of frequency. The performance of the spectrometer is determined by the AO light deflector and the image-sensing circuitry. The piezo-electric transducer and the AO material limit the band width and the frequency resolution (Uchida and Niizeki 1973; Kaifu et al. 1977). The TeO_2 deflector has the high efficiency of the AO interaction and very slow sound velocity. This makes it possible to build a compact and therefore stable spectrometer with 10^3 resolvable points. The image-sensing circuitry itself contains undesirable noise sources. The noise arises mainly from the photo-detector array, which has a signal-to-noise voltage ratio (R) of 300:1 to 1000:1, measured after square-law detection. In order not to degrade the S/N ratio of the receiver, the following inequality must be satisfied (Chikada 1978):

B. H. Andrew (ed.), Interstellar Molecules, 625–626.

$$D^2 \times \Delta f \times \tau << R^2,$$

where Δf and $1/\tau$ are the frequency resolution and the frame rate of the image-sensor scanning, respectively, and D stands for the dynamic range over the total bandwidth. The pass-band is not flat over the full frequency span and, if a deviation of 3 dB is allowed, D^2 becomes greater than 4. The performances of the spectrometers are summarized in the table below.

		TAO		KTC
Bandwidth	(MHz)	39	220	230
Resolution	(kHz)	38	275	2000
Freq. channels	(bins)	1728	1728	256
Freq. spacing	(kHz)	23	127	1000
S/N degradation*	(dB)		1	1

*Worst case with weak signal.

The Large Radio Telescope Project is now at the stage of constructing antennas. The acousto-optic spectrometers are to form a part of a receiver back-end system with an instantaneous bandwidth of 2 GHz and 10^4 frequency channels.

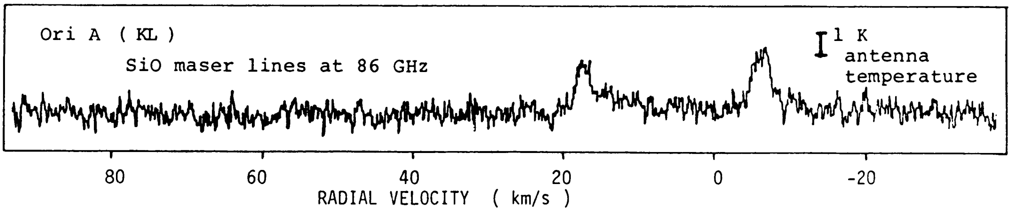

Figure 1. SiO maser lines observed with the 1728 channel AOS of TAO.

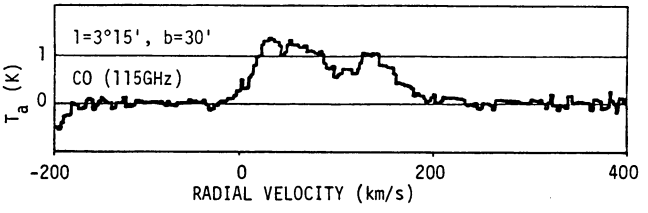

Figure 2. CO emission observed with the 256 channel AOS of KTC.

REFERENCES

Chicada, Y.: 1978, private communication (in Japanese).
Kaifu, N., Ukita, N., Chikada, Y., and Miyaji, T.: 1977, Publ. Astron. Soc. Japan 29, pp. 429-435.
Lambert, L.B.: 1962, Inst. Radio Engrs. Intl. Conv. Rec. Pt. 6,10,p. 69.
Uchida, N., and Niizeki, N.: 1973, Proc. Inst. Elec. Electron. Engrs. 61, p. 1073.

https://doi.org/10.1017/S0074180900073393 Published online by Cambridge University Press