MMA Project Book, Chapter 7 Section 1

PHOTONIC LOCAL OSCILLATOR SYSTEM

John Payne
Bill Shillue
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Summary

Recent commercial developments in the optical fiber industry have raised the possibility of supplying the local oscillator signal for the MMA by generating two optical signals differing in frequency by the required local oscillator frequency. These two optical signals may then be transmitted over a single optical fiber to each antenna. Within the receiver dewar, the two optical signals are mixed in a photodetector and the resultant millimeter-wave frequency difference supplies the local oscillator power.

Table 7.1 Principal milestones for photonic local oscillator.

	Task	Completion Date
1)	Demonstration of adequate spectral purity between phase-locked lasers.	Done 8-98
2)	Test and evaluation of 100 GHz photodetector	03-99
	Future developments depend on the outcome of task #2.	

7.1.1 Introduction

The local oscillator system for the MMA presents a great challenge for the instrument builders. The generation of a pure frequency with high phase stability in the frequency range of 90-900 GHz at each of forty antennas, and preserving the phase relationship between antennas for long (perhaps hours) periods of time, is perhaps the most difficult part of the instrument. Although, in theory, the task could be completed with components available today by adopting the conventional route of a phase-locked oscillator at a frequency of around 100 GHz, followed by multipliers, the cost and complexity are daunting. There have been recent developments in the so called "conventional" techniques that suggest that the reliability and cost of this approach may be greatly improved by the application of new beam lead diodes and MMICs, and we are pursuing this approach as described in Section 2 of this Chapter.

However, recent advances in laser diode technology and optical fiber transmission systems raise the possibility of a local oscillator system for the MMA, based on the mixing of two optical signals separated by the required local oscillator frequency. Such a system could be realized using mainly commercially available components, resulting in significant savings in both cost and manpower when compared to the conventional approach of a phase locked oscillator followed by passive multipliers. This approach is so attractive that we have mounted a development effort to investigate the feasibility of such an approach.

Several groups have worked on systems similar to this. The phase-locking of the beat note between two infrared lasers to an external microwave standard, with the spectral purity required of the MMA, was first demonstrated many years ago and is now regarded as routine. (For references and more details, see MMA memo #200). Beat notes of up to several THz have been demonstrated with a cooled fiber-coupled photomixer at power levels that appear to be marginally adequate for supplying the LO to the SIS receivers on the MMA. New detector fabrication techniques hold the promise of increased power levels in the wavelength range of the MMA.

The potential advantages of such a system may be summarized as follows:

The majority of the components needed for the realization of the proposed scheme are commercially available. The communications industry has a huge investment in optical fiber systems, and the system outlined here exploits these fairly recent developments. We can be certain that intense development in this area will continue.

(1) All of the frequency synthesis components of the local oscillator system may be situated in a laboratory environment remote from the array. At the antennas, only some leveling electronics and a photomixer are required. In terms of serviceability and reliability, this is regarded as a great advantage.

(2) The receiver interface is greatly simplified. Due to bandwidth requirements, the usual Martin-Puplett quasi-optical LO injection scheme will not be appropriate. LO injection using conventional methods with waveguides entering into the cryogenic enclosure (for each receiver band) would involve a relatively high loss and would complicate the thermal design of the receiver. In contrast, all that will be needed in the photonic system is one optical fiber into the receiver dewar resulting in negligible heat load. Vacuum feed-throughs for fiber are fully developed commercially.

(3) There is a great reduction in complexity .

(4) The proposed system eliminates the need for the usual microwave harmonic mixers.

(5) The real cost promises to be far less than a conventional system.

(6) In the conventional system the passive multipliers following the fundamental oscillator introduce additional amplitude and phase noise. Investigation is needed here but it seems possible that noise on the fundamental oscillator may be multiplied by the square of the multiplication ratio. In the case of multiplying from 100 GHz to 800 GHz, phase noise enhancement by factor of 64 may well be involved which could prove unacceptable for use in the array. It may be that such an effect is absent in the case of the photonic system although work is needed to settle this question.

Details on the following are given in MMA Memo 200 , Photonic Local Oscillator for the MMA.

(1) MMA LO requirements.

(2) Description of proposed system.

(3) Theory of photo-mixing.

(4) Expected performance.

(5) References.

7.1.2 Critical Issues

There are many issues to be decided in the implementation of such a system. These decisions are made more difficult by the rapid development in the microwave photonics field. At the present time the tentative choices that we have made are as follows.

7.1.3 Wavelength of Operation

There are two so-called " communication windows " in fiber optic communications at present: the 1.3 micron window in which fiber dispersion is minimum, and the 1.5 micron window in which fiber attenuation is minimum. The 1.5 window seems to be in favor with industry at present, and at least one prominent manufacturer has announced the discontinuing of components for the 1.3 micron band. Also, although it is not yet known if dispersion will be a problem, a special zero-dispersion fiber is available at 1.5 micron for a nominal extra cost. Therefore, we have, provisionally, adopted the 1.5 micron band for our development.

7.1.4 Choice of lasers

The power output and spectral purity of lasers in the 1.5 micron band is improving rapidly. There are two types of lasers that seem to have the potential to be satisfactory for our application. These are the external cavity diode laser and the erbium doped fiber laser. The erbium doped fiber laser has greater power output and narrower line width than the external cavity laser but phase locking of these lasers has not been demonstrated, at least to our knowledge. The external cavity lasers are easily phase lockable to an external microwave reference and we have conducted measurements on a pair of rented lasers and reached the conclusion that the spectral purity is adequate for our purposes. It may well be that our initial choice of external cavity diode lasers is not the optimum one . As part of our development program, we intend to test other types of lasers as the state-of-the-art advances.

7.1.5 Choice of detectors

The photo detector is the key element in the proposed scheme. Although beat frequency detection of up to several terahertz have been reported, the power levels have been marginal for our application. There are several types of photodetectors in use at high frequencies, and we have chosen to adopt the approach pioneered by UCLA: the velocity matched photodetector. A description of this and other detectors in use are given in MMA Memo # 200. We have a contract with UCLA to initially develop a photodetector producing 100 micro-watts of power over the 75-110 GHz band. The design is such that we believe that it will be scalable to the higher frequencies.

7.1.6 Development Course

As with many development projects the time scales are uncertain but the following (Table 7.2) is an estimate of the times for the various tasks that have to be completed to bring the development project to completion.

Table 7.2

Task		People	Completion Date
1)	Set up two external cavity lasers phase locked to a microwave ref. Measure phase and amplitude noise at beat frequencies up to 18 GHz.	1 EE	8-98
2)	Design and build the optical comb generator.	1 EE + ½ Tech	2-99
3)	Test comb generator up to 80 GHz using commercial detectors.	1 EE + ½ Tech	5-99
4)	Test and evaluate 100 GHz UCLA photo-detector	1 EE + ½ Tech	9-99
5)	Test and evaluate UCLA photo-detector at 230 GHz	1 EE + ½ Tech	12-99 (Note 1)
6)	Complete laboratory test using two 230 GHz photodetectors.	1 EE + ½ Tech	5-00