A New Laboratory for Terahertz Photonics

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***Abstract*—We are currently setting up a new photonics laboratory at the Electrical Engineering Department of the University of Chile. We describe the planned research in this laboratory, which will be devoted to the application of terahertz photonics in radioastronomical instrumentation and will be two-fold:**

First, the distribution of ultra-stable terahertz phase references through long fiber links will be investigated while participating in the current testing and commissioning of the central photonic local oscillator system of ALMA. This would include investigation of sources of phase drifts, the impact of polarization mode dispersion (PMD) to the ultimate phase instability of a fiber link, and new line-length correction schemes to include PMD correction. For this we acknowledge the support from the ALMA project (Backend-LO-group at NRAO Charlottesville and ALMA AIV Santiago).

Second, more efficient continuous-wave photonic near-infrared mixers as terahertz sources will be investigated within international collaborations with the motivation to develop a universal photonic local oscillator for astronomical submillimeter/terahertz receiver systems. Continuing previous own work, new concepts of vertically illuminated traveling-wave (TW) photomixers will be investigated. Miniaturization of the TW-optics for fiber-pigtail integration, device simulation/modeling and optical/terahertz testing will be done within our lab, whereas device fabrication at the facilities of a collaboration partner. Here we greatly appreciate possibilities for collaborations with J. Stake, Chalmers Technical University and J. Campbell, University of Charlottesville.

***Index Terms*— heterodyne detection, high-speed optical techniques, optoelectronics, microwave oscillators, microwave photonics, millimetre wave generation, optical transmitters, optical fibers, photodetectors, Interferometry.**

I. INTRODUCTION

The laboratory introduced here is devoted to the application of photonics in astronomical instrumentation and will be two-fold: First, the ultra-phase-stable distribution of terahertz reference signals through long fiber links will be investigated along a cooperation with the ALMA project for commissioning the central photonic local oscillator of ALMA (PLO). [1] Second, more efficient terahertz sources based on photonic near-infrared mixers will be investigated within international collaborations for use as universal local oscillators in astronomical submillimeter/terahertz receiver systems[2]. This new laboratory dedicated to research on photonic terahertz-sources and on terahertz reference fiber links is being set up at the Electrical engineering department..

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II. TERAHERTZ PHASE REFERENCE FIBER LINKS

Polarization mode dispersion (PMD) is a phenomenon caused by birefringence of the fiber, which means that the light velocity is dependent on the state of polarization (SOP). There are two orthogonal principal states of polarization (PSP, see fig. 1, generally could be any elliptical polarization), in which the velocity is maximal or minimal.

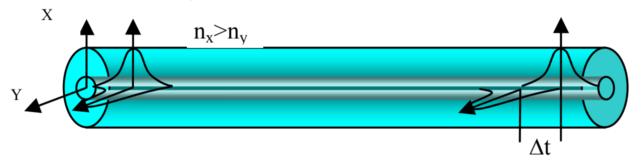

Fig. 1. Effect of PMD in the time of flight of pulse traveling through a fiber, depending on the polarization of the light relative to the PSP of the fiber.

This effect can produce instability of the state of polarization at the input of the photomixer, adding the requirement of polarization independency of this device. If this requirement is not fulfilled by the photomixers, PMD causes larger instability of the phase and power of the RF beat note at the output of the photomixer. [3]

All of this adds risks to the ALMA PLO system, so it is important to quantify these effects on the final on-site performance.

Fig. 2 shows the setup proposed to the ALMA integration and verification team (AIV). The objective of it is to measure the PMD behavior of the system and its effect on the phase stability of the system, and Fig. 3 shows the proposed setup to evaluate the polarization stability of the PLO signal.

Other research projects within this line of research are: 1.) a new optical delay modulator scheme for the line length corrector system (LLC) of ALMA (Fig. 4), based on free-space optics in a length-controlled multipass-cell instead of a fiber-stretcher, and therefore avoids any polarization activity. 2.) a new holographic type of n-way beam splitter, to replace the current beam splitter in the fiber distribution scheme of the ALMA Photonic LO (PLO), see Fig. 5. The goal is to reduce a big risk of ALMA: Because these beamsplitters are outside the phase correction loops for the individual fibers to the antennas, the measured uncontrollable polarization-to-phase coupling effects of the commercial n-way splitters available up to now will cause an increasing degradation of the resolution performance of ALMA towards higher frequencies.

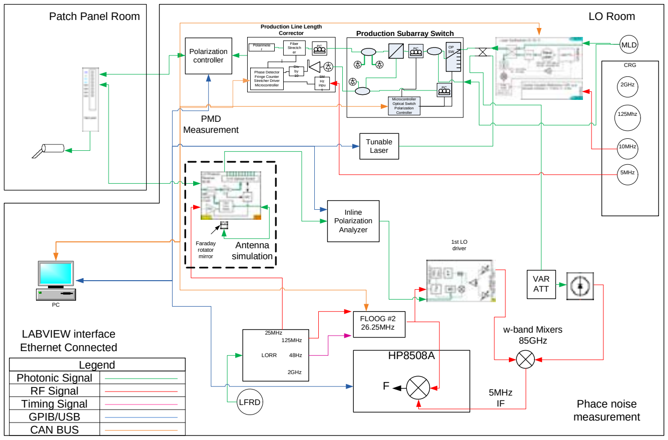

Fig. 2. this figure shows the proposed setup. to make the evaluation of the phase stability measurement of the ALMA LO photonic distribution system, and its dependency on PMD.

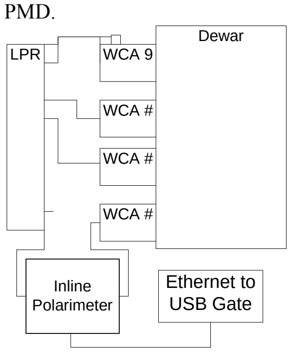

Fig. 3. Setup proposed to evaluate the polarization stability of the ALMA LO photonic distribution system.

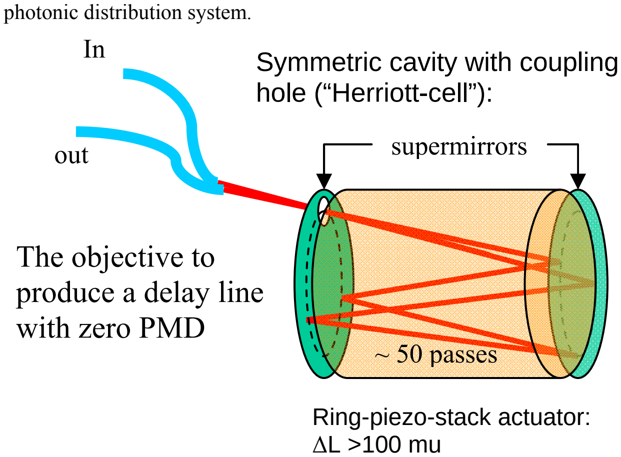

Fig. 4. New optical delay modulator schemes

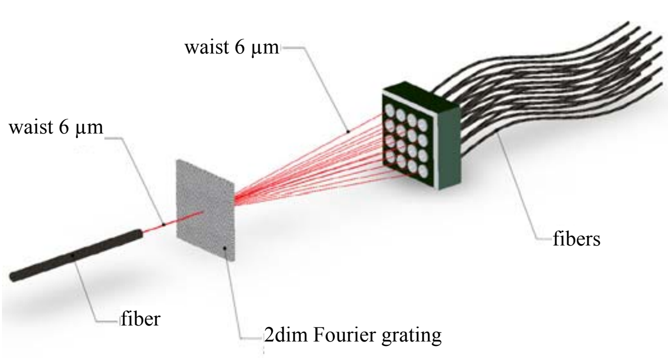

Fig. 5. Holographic n-Way splitter

III. Photonic Terahertz Source: Optical Heterodyning

The second line of research is devoted to the development of more efficient continuous-wave photonic near-infrared traveling-wave photomixers as terahertz sources. This will be investigated within international collaborations with the motivation to develop a universal photonic local oscillator for astronomical submillimeter/terahertz receiver systems. After design and simulation, the devices will be fabricated through these collaborations and finally characterized optically in our photonics lab, where we have a photomixer test bank, as shown in the

Fig. 6 left, which has been used during recent work to develop vertically pumped traveling-wave (TW) planar structures based on LT-GaAs [4][5] (see Fig. 7).

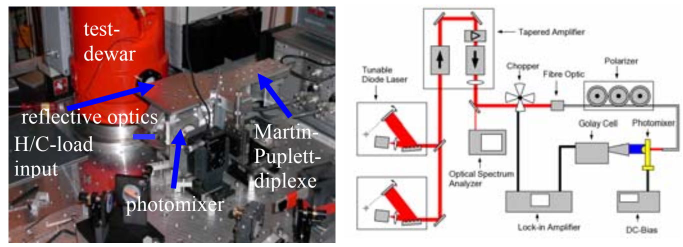

Fig. 6. left: Photonic local oscillator test setup for TW-photomixers; right: Fiber-based test setup for lumped-element photomixers

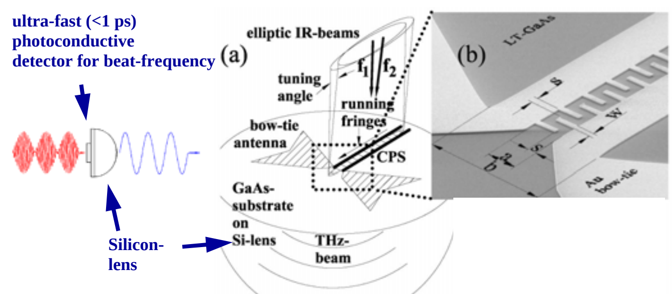

Fig. 7. Planar travelling-wave (TW) structures based on LT-GaAs (operational wavelength 0.780 µm): (a) Velocity-match of IR interference fringes to the THz-wave by a tuning-angle between the two heterodyned IR beams; (b) planar structure with inner part of bow-tie antenna.

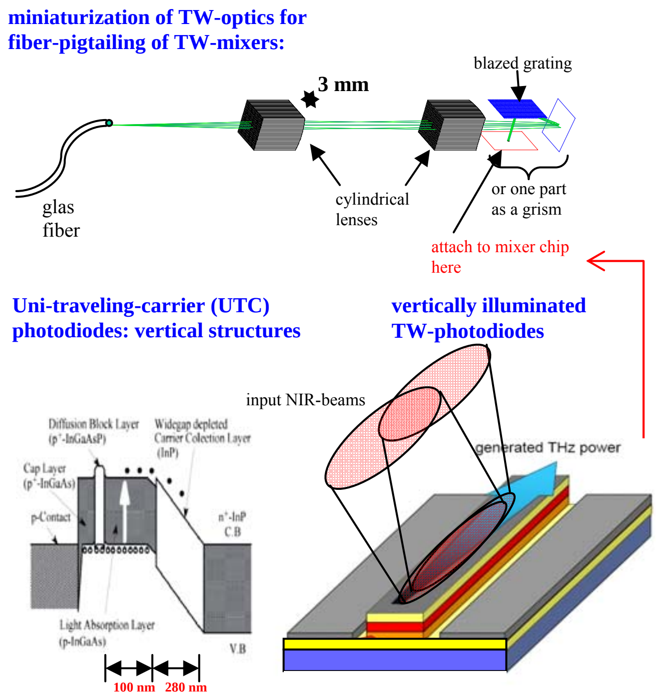

Fig. 8. top: Miniaturized optics for vertical illumination of traveling-wave photodiodes; bottom: scheme of proposed work on vertically illuminated uni-traveling-carrier (UTC) photodiodes implemented in a traveling-wave structure.

ACKNOWLEDGMENTS

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