ALMA Photonics Development

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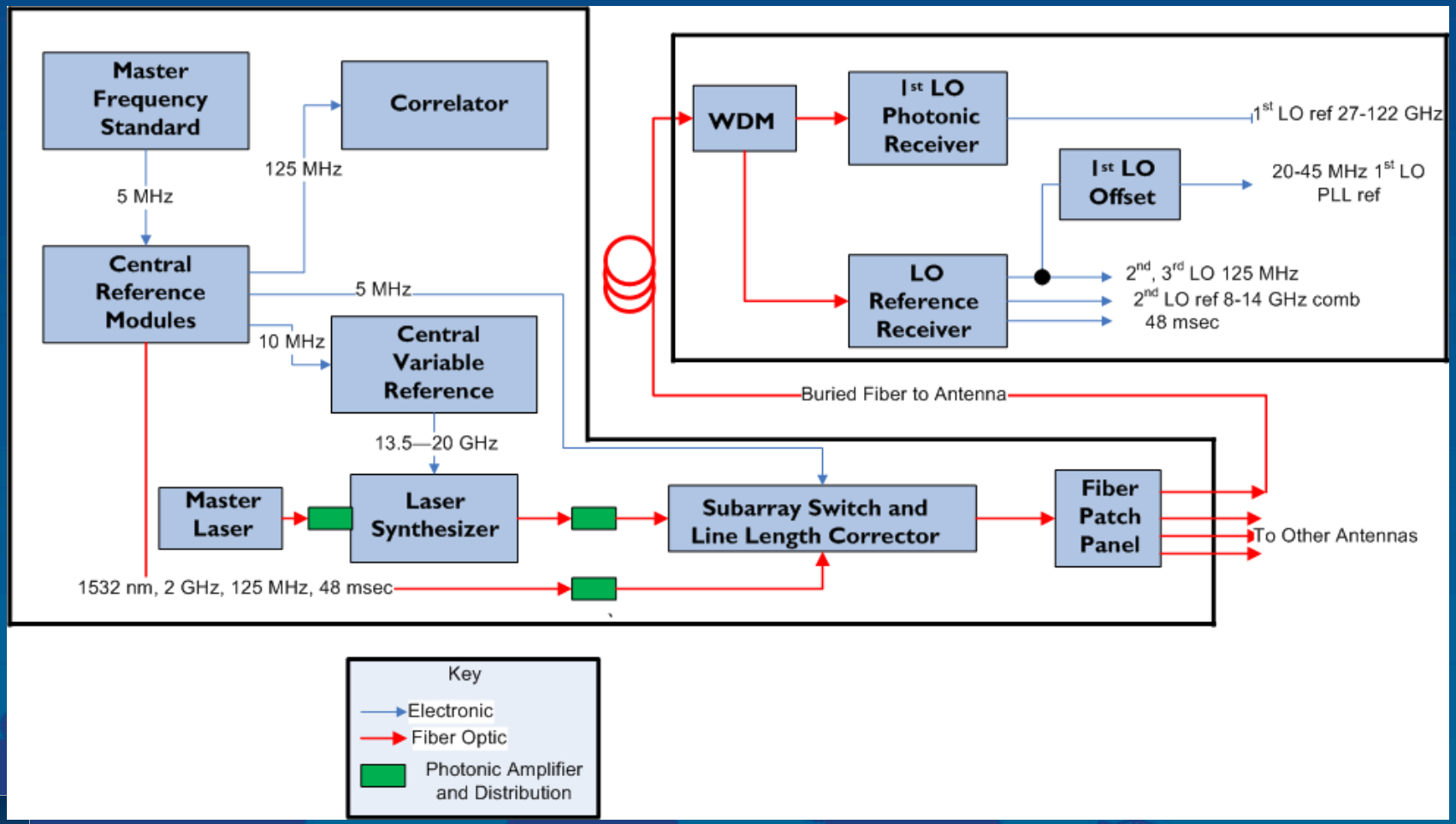
Introduction

- Photonic LO – what it is
- Status of Photonic LO
- A few areas of possible development effort

ALMA Central LO: Top Level Description



Photonic Local Oscillator Function

- To provide a ***continuously tunable*** (27-122 GHz) ***fast-switching*** 1st LO Reference with ***low phase noise and drift***
  - Phase Noise < 38 fsec 1Hz—10 MHz (< 53 fsec 1st LO)
  - Phase Drift <12 fsec over 300 sec (< 18 fsec 1st LO)
  - Frequency Band Switching Speed < 500 msec

    Band 1 27.26—33.05 GHz

    Bands 2-10 65.46—121.712 GHz

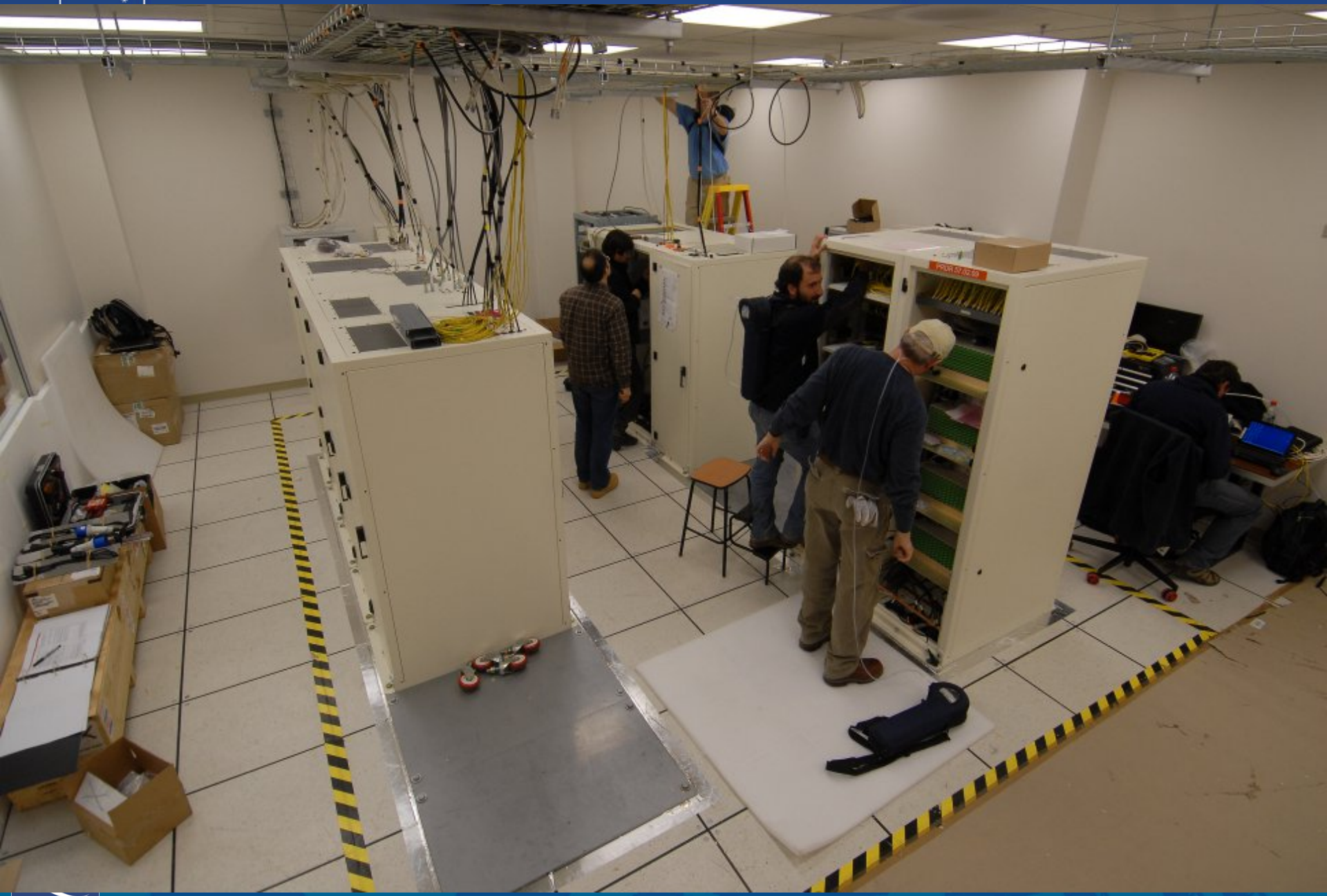
- Up to six independently tunable Subarrays (only four in Construction!)
- Generate all Low Frequency RF References and distribute these by optical fiber to each antenna, as well as to the Correlator
- Combine and distribute the 1st LO Reference (1556-1557 nm) and Low Frequency References (1532 nm) to Antenna Receivers by optical fiber – stabilized to within13 fsec over 10^2—10^3 seconds

Current Status

- March/April conversion from CLOA1 to CLOA2
  - CLOA1: two subarrays, 16 channels
  - CLOA2: four subarrays, 32+ channels

NRAO


THIS END UP
FRAGILE
Do not stack



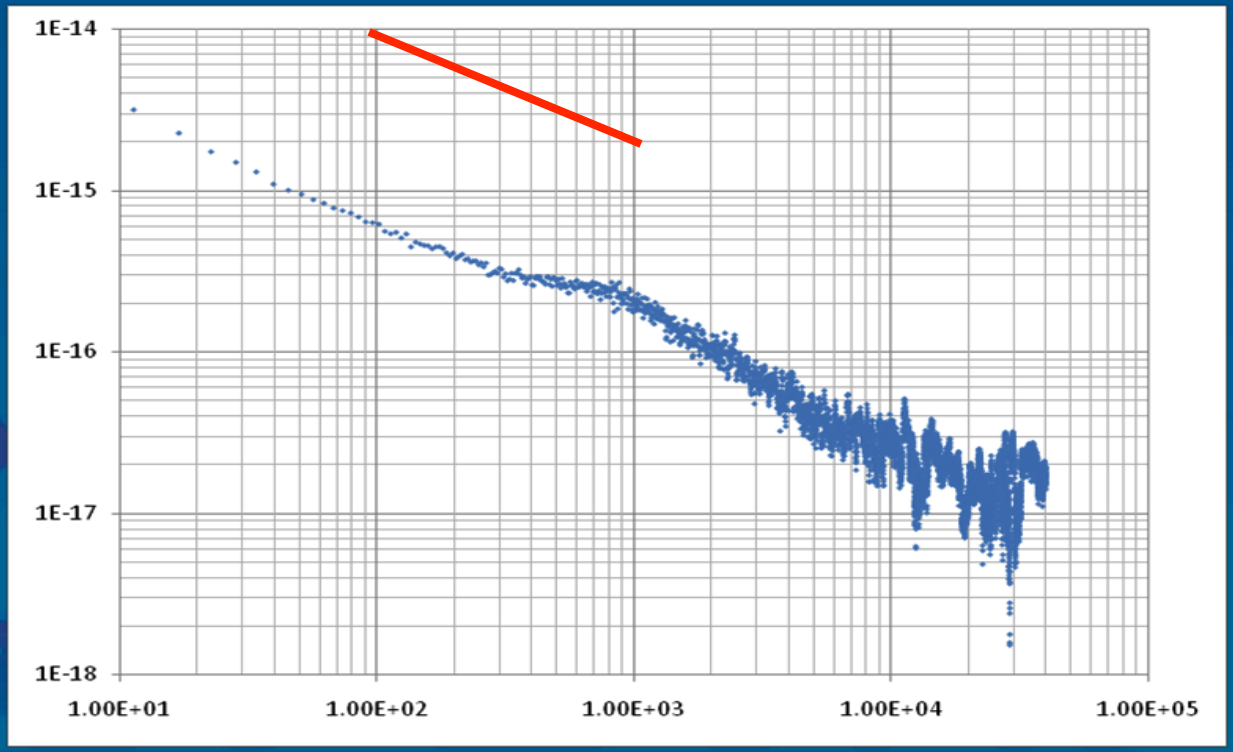

PRDR 57.02.09
SASR 57.02.08


CVRR 57024 11
CVRR 57024 10


LLCR-ACA 57.02.03
LLCR-B2 57.02.03

Performance Summary

- The Central LO meets the ALMA specifications for tuning range, tuning speed, phase noise, phase drift.
- The Central LO is well ***under*** the required stability for VLBI



System Design and Test

- The system is tested extensively before shipment and after installation
- Tests are done at all frequencies, all outputs, with test iterations in the tens of thousands
- Required:
  - Good temperature stability in LO room
  - Low PMD fiber, buried for good thermal stability
  - Low impact fiber wrap to minimize effect of antenna motion
  - In several locations, passive fiber length matching is used to guarantee low phase drift. Hundreds of optical fibers are carefully measured to length.
- New development must take into account the system integration

What can be "added" ?

- Two Subarrays
  - Fixed cost, procure and install (not a development project)
  - Two Laser Synthesizers
  - Two Central Variable Reference synthesizers
  - Two Photonic Reference Distribution units
  - Some cabling
- Up to 80 channels
  - One Subarray switch and one LLC per channel
  - If ALMA adds antennas for $$$, Central LO can support total up to 80 for $

What can be improved?

ALMA Central LO is meeting specifications

There are several known causes of residual phase drift, but in general small performance improvements can be made at large cost. In other areas we may need more observing time for us to know whether further development effort is worthwhile.

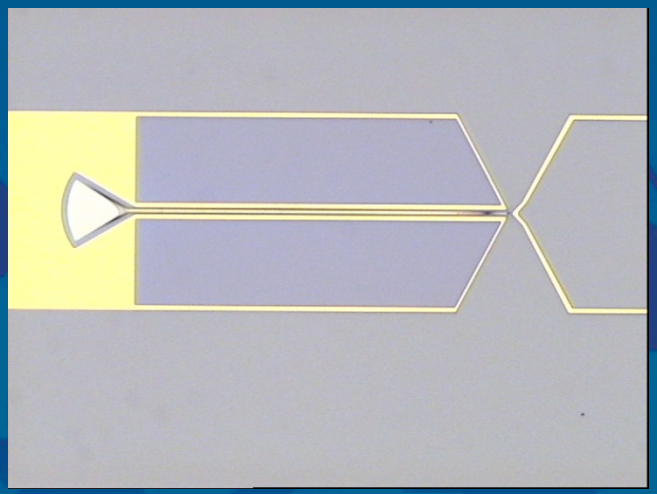
For purposes of this meeting, only a few upgrade areas will be discussed

- Improved photomixer for better phase drift performance, improved visibility
- Improved Line Length Correction fringe counter for software phase correction, improving operational flexibility
- Improved Phase Noise for Band 8,9,10,11 Science Array coherence

Possible (modest) Improvements

Photomixer:

- ALMA Photomixers have high polarization to phase conversion due to a birefringent optical waveguide on the photodiode structure. Future photomixer development could eliminate this and improve overall LO phase drift performance.
- Univ de Chile has a development effort in progress:



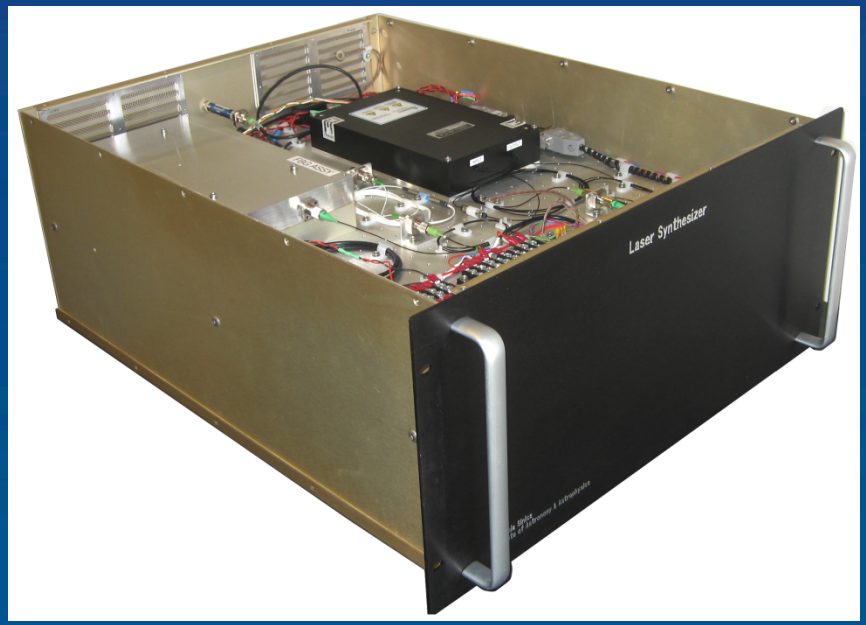
Possible (modest) Improvements

Line Length Correction by Software

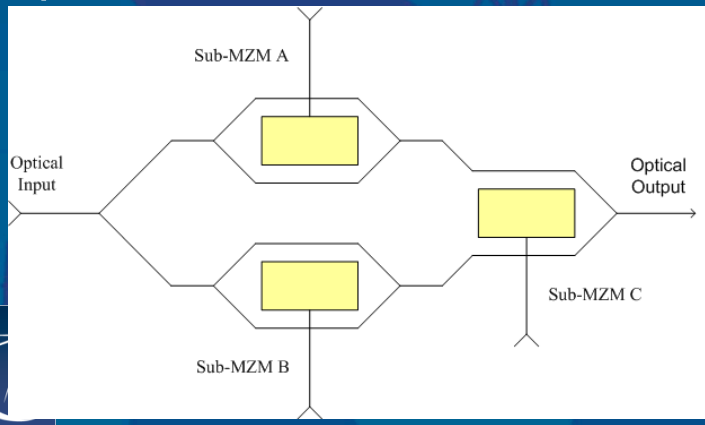
- Currently the ALMA Line Length Corrector has a fringe counter that measures open loop phase change. This was included as a diagnostic feature in the electronics. There has been interest in using this as the basis for a software phase correction. The impoved system could operate in closed-loop hardware correction mode or in software correction mode.
  - Improve operational flexibility
  - Improve reliability
  - Requires redesign of electronics and replacement of all LLC electronics cards, moderate cost

MZM-Laser Synthesizer

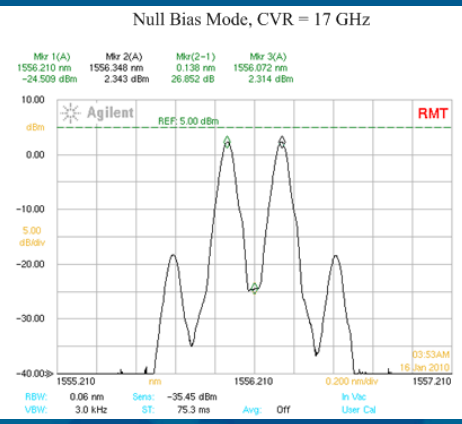
The Mach-Zender Modulator Laser Synthesizer developed by Kiuchi (NAOJ) has a superior phase nose characteristic to the ALMA two-laser Laser Synthesizer

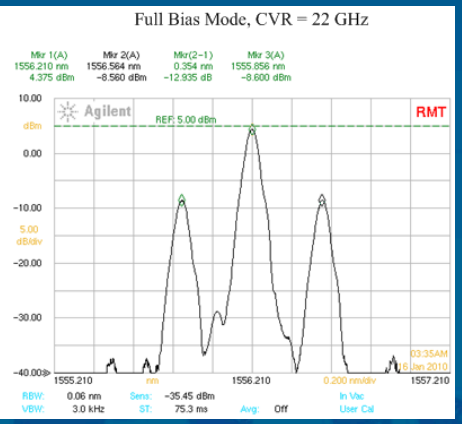


With Kiuchi-san as consultant, ASIAA has built a full prototype, which meets the ALMA tuning and phase noise performance specifications



Sumitomo LiNbO3 MZ Modulator





Optical Output Spectra from MZ Modulator

MZM-LS Interface Testing

- The MZM-LS prototype is highly developed and well characterized
- The only concern was whether it would interface with the ALMA Central LO properly
- The unit was tested extensively with the ALMA Central LO in Charlottesville, Sept 2010
- The MZM-LS worked with the ALMA line length correction and locked 1st LO WCAs
- However, when frequency switching the MZM-LS has a fundamental incompatibility due to the fact that there is no fixed (master) laser on the output.
- A solution was found in which the MZM-LS uses a different reference wavelength, and the master laser is used for the line length correction but not for the LO reference.
- This solution was tested in frequency switching mode with two complete LO assemblies and results met the ALMA specification.

MZM-LS Coherence Improvement

- With MZM-LS the 1st LO Phase noise is reduced from ~53 fsec to <= 30 fsec
- This can yield a direct array coherence improvement
- Some estimates are shown below

Frequency	Coherence – atm, elec, antenna	Coherence LO	Coherence total
950 GHz Baseline	.74	.90	.67
950 GHz MZM-LS	.74	.97	.72
1.6 THz Baseline	.43	.75	.32
1.6 THz MZM-LS	.43	.91	.39