Atacama Large Millimeter Array Local Oscillator: How Photonics is Enabling Millimeter-wave Astronomy

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Abstract: In this talk we will describe the unique photonic technology that provides the reference for the local oscillator system of the ALMA millimeter wave radio telescope as well as describing the "down-stream" part of the local oscillator system.
OCIS codes: (110.6770) Telescopes; (111.5100) Phased Array Imaging Systems

1. Introduction

ALMA [1], the largest astronomical project in existence, is a revolutionary telescope, comprising an array of 66 giant 12-meter and 7-meter diameter antennas observing at millimeter and submillimeter wavelengths. ALMA will start scientific observations in 2011 [2].

Figure 1. A working interferometer of eight ALMA antennas at the high site around September 2010. Credit: ALMA (ESO/NAOJ/NRAO), S. Argandoña (ALMA)

ALMA is a coherent instrument in that the output of each antenna is in phase with an accuracy of about 6 micron with respect to any other antenna in the array which can be as much as 15 km distant. Providing the stable, low noise, phase reference to these antennas is the main subject of this talk. ALMA uses heterodyne SIS mixer receivers to down convert the sky signal to an IF signal which is digitized and transmitted to a central correlator.

For good interferometric visibility, delay errors of the first LO reference signal must be < 18 fsec over time scales of approximately 300 seconds. For high coherence short term rms phase errors must be <53 fsec. Since the superconducting SIS mixers used in the receivers are single ended devices, this LO signal must also have 160 dB signal to noise ratio. A further requirement is that the Local Oscillator must be electronically tunable with no mechanical tuning.

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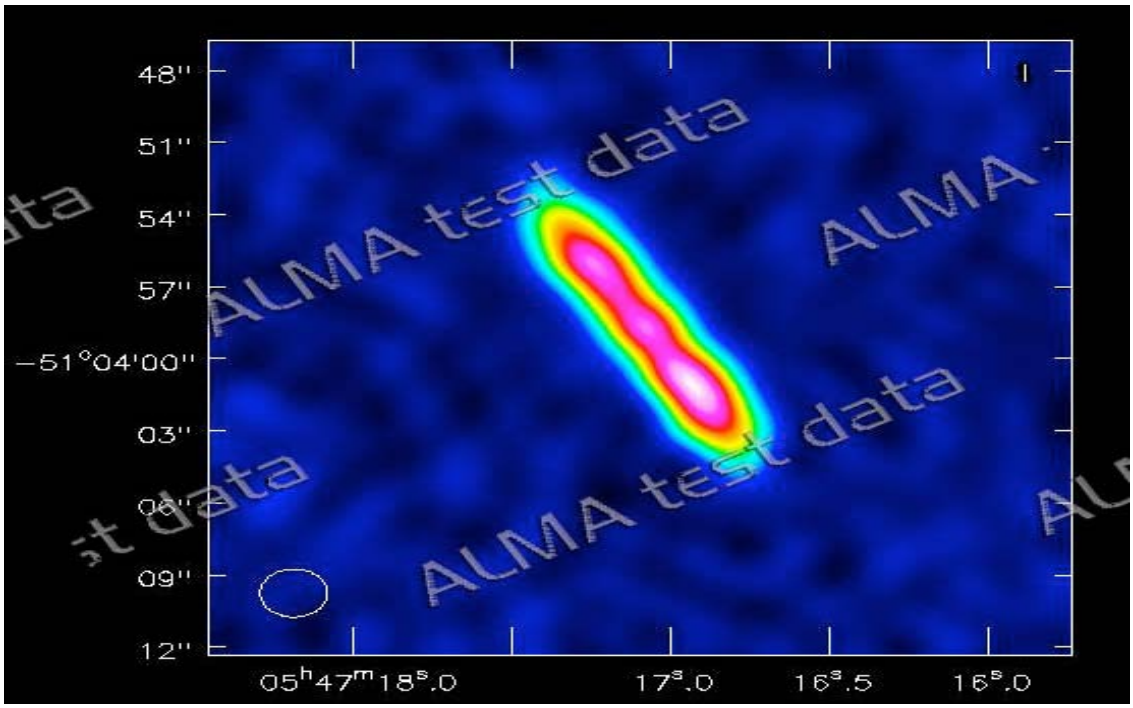

Figure 2. This shows the ALMA test data at 870 microns showing the denser material in the central region emitted from the disk of dust surrounding the star Beta-Pictoris

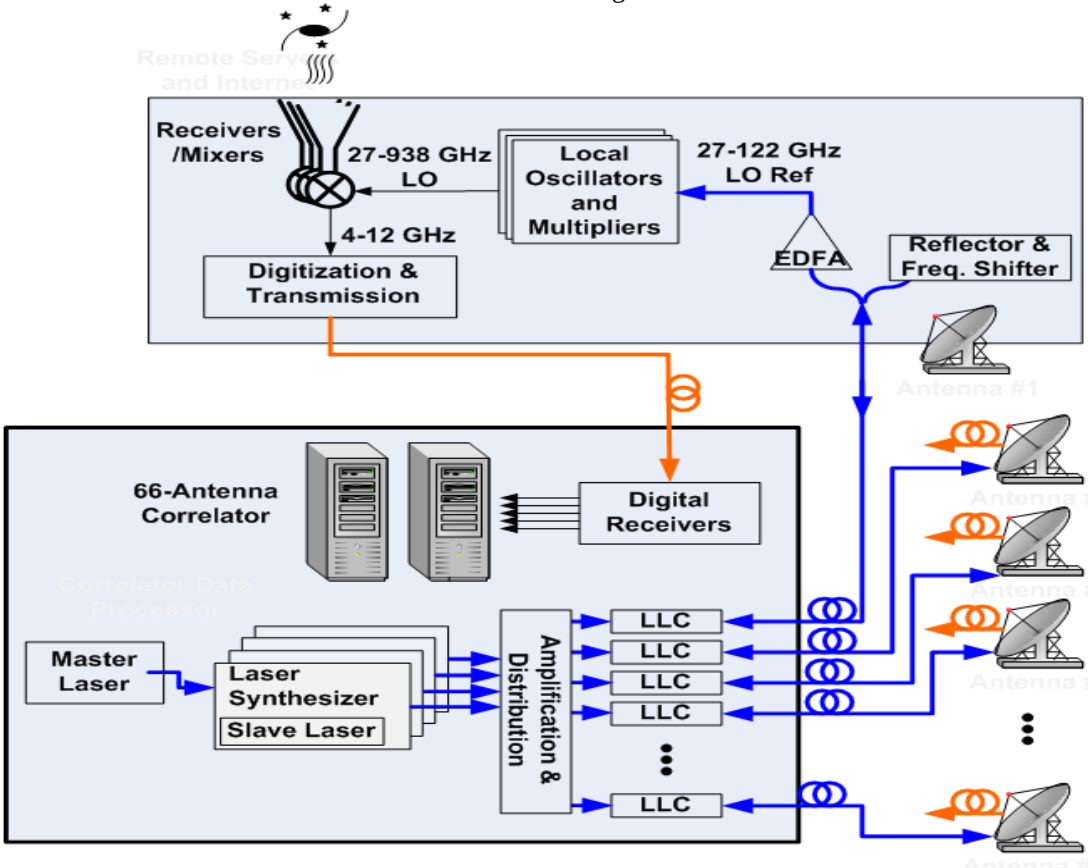

Figure 3 Overall Block Diagram of the ALMA system, with the LO reference distribution and ALMA receiver. [3]

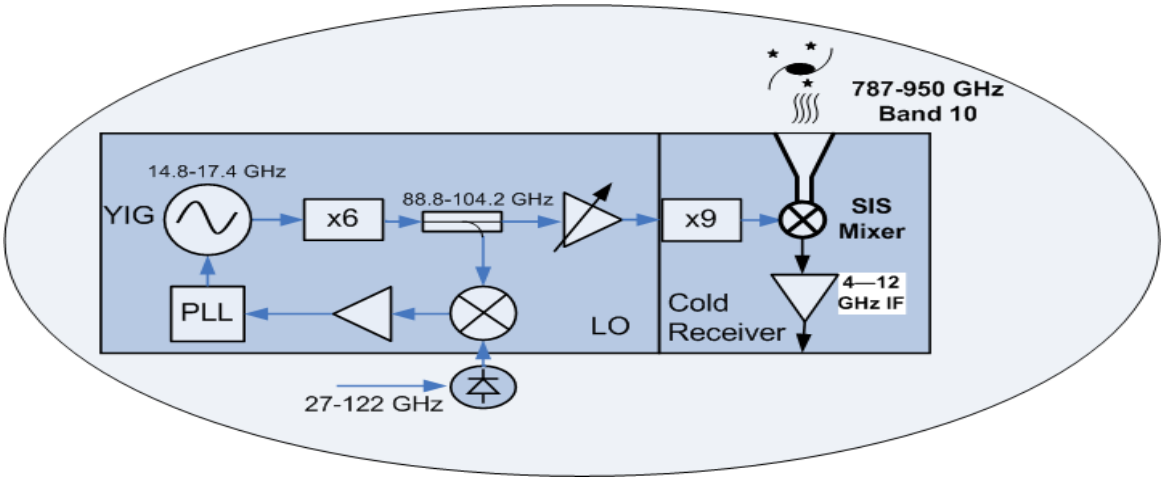

Figure 4 Detailed Block Diagram of the Local Oscillators and Multipliers

4. References

[1] The Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Organization for Astronomical Research in the Southern Hemisphere (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

[2] It is anticipated that the ALMA Director will issue a Call for Proposals for Early Science in the first quarter of 2011. That announcement will provide more details of the expected timeline and capabilities to be offered.

[3] Cliche, J.-F., Shillue, B.," **Precision timing control for radioastronomy: maintaining femtosecond synchronization in the Atacama Large Millimeter Array**," in Control Systems Magazine, IEEE Volume 26, Issue 1, Feb. 2006 Page(s):19 - 26