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When Tucson's Modern Streetcar came to town, NOAO's Optics Shop turned to 4D's Dynamic Interferometry to measure despite the vibration.

Measuring Precision Telescope Optics (with a Streetcar Outside Your Door)

Introduction

Tucson Arizona's Modern Streetcar Project, now in its construction phase, was devised as a sustainable transportation option that would connect the city center, the University of Arizona, the Arizona Health Sciences Center and several residential, historic and shopping districts.

During the Modern Streetcar Project's development phase, concerns were raised by the National Optical Astronomy Observatory (NOAO) that vibration generated by passing streetcars would inhibit or prevent measurements made at its Optics Shop, located on the University of Arizona campus (Figure 1). The facility coats, tests and assembles telescope optics and systems, including optics for the 3.5 meter WIYN Telescope on Arizona's Kitt Peak.

According to Gary Poczulp, NOAO's Optics Shop and Coating Lab Supervisor, the staff was worried that vibration generated by the streetcar would prohibit interferometric measurements within the facility. The facility already deals with a high degree of ambient vibration, particularly at times when traffic is high on nearby roads. Its large testing rigs are not vibration isolated, which has required technicians to make measurements during off hours, with air handling equipment turned off. NOAO staff believed that vibration from the streetcar, which is scheduled to pass the facility potentially every 10 minutes from 6am through 11pm, would severely restrict its ability to make accurate measurements, which would in turn limit the facility's productivity and potentially delay critical projects.

Figure 1. The Tucson Modern Streetcar will pass within 100 feet of NOAO's Optics Shop on the University of Arizona campus.

4D Technology
Optical Metrology for a Dynamic World

Testing for Vibration Impact

Shellie Ginn, Program Manager for the Tucson Modern Streetcar, noted that there was the potential for several research facilities on the University of Arizona campus to be affected by the project, both by vibration and by electromagnetic fields generated by passing streetcars.

In response to the NOAO concerns, the Modern Streetcar Project hired ATS Consulting, a Pasadena, California based acoustical consulting firm, to analyze the streetcar's potential impact. The firm used a technique called Vibration Propagation Testing to simulate the effect of a passing streetcar and placed accelerometers throughout the Optic Shop's coating and fabrication areas to measure the effects.

According to an ATS memorandum:

- The predicted streetcar vibration exceeds the measured nighttime ambient vibration in the low frequency range when most HVAC systems are turned off
- Because the predicted streetcar vibration exceeds the measured nighttime ambient vibration in some frequency ranges, streetcar operations may cause vibration levels that would interfere with interferometer tests in the Optics Lab.[1]

Several options were considered to mitigate the effects of vibration, including installing vibration isolation for equipment in the facility and incorporating vibration isolation into the track design. Both of these options required massive isolation structures and were prohibitively expensive. Relocation, a solution employed for another University laboratory along the route, was not possible for the Optics Shop due to the massive size of its equipment. Restricting the hours of measurements in the Shop would greatly limit the facility's productivity, while limiting the hours of operation for the streetcar would diminish its effectiveness and jeopardize its fiscal well-being.

A Vibration-Insensitive Testing Method

According to Poczulp, at this point NOAO staff suggested a different approach and began investigating laser-based instruments that are capable of high-precision measurement even in the presence of vibration and motion.

In traditional, "phase-shifting" laser interferometry, which can measure surface shape down to nanometer levels, multiple frames of measurement data are acquired sequentially over hundreds of milliseconds. This acquisition time is very long relative to environmental noise such as vibration and air turbulence. Vibration isolation is possible and can help, but it is extremely expensive on the large scale required by the Optics Lab's testing setup.

Over the last decade, several companies have introduced technologies that enable laser interferometry to be used without isolation. One such method, Dynamic Interferometry®, was introduced by Tucson-based manufacturer 4D Technology Corporation. In Dynamic Interferometry, all measurement data is acquired simultaneously in a single camera frame. The entire acquisition cycle is completed in less than a millisecond, more than a thousand times faster than phase-shifting interferometry. Such fast acquisition time enables measurements to be made despite vibration, without additional isolation. Averaging multiple measurements removes the effect of air turbulence as well. Dynamic Interferometry, therefore, offered a potential solution to streetcar vibration, and at a cost of approximately 1/10 that of other proposed mitigation methods.

Demonstrations from several vendors were held for NOAO and Modern Streetcar Project management to prove the feasibility of the method. According to Poczulp, "While the City of Tucson people had agreed in principle that a vibration-insensitive interferometer was the way to go, they were interested in seeing how such a piece of equipment would be able to mitigate our anticipated vibration problems." The demonstrations successfully showed the technique's merits, and a solution appeared to be at hand.

Figure 2. 4D Technology's AccuFiz Interferometer with dynamic measurement option.

4D Technology was ultimately selected as the vendor to provide the interferometer. According to Poczulp, 4D's AccuFiz® interferometer (Figure 2) was selected because of its small size, which allows the instrument to be moved easily between test stations and facilities, and the flexibility of its software, which would enable the system to be used for a range of future measurement work as well as for the current projects at the facility. The interferometer also gave the shop significantly improved resolution and precision compared with its older, traditional measurement equipment.

According to Shellie Ginn, project managers were particularly happy that they were able to find a solution from a local vendor. "What are the chances of finding the solution in Tucson? That usually doesn't happen," said Ginn. "We would have found a solution to the vibration problem no matter what, but this option made the most sense. We were able to improve the working environment [at the Optics Shop] and at the same time support the local economy."

The AccuFiz interferometer was delivered to NOAO in December, 2011 and is now in service at the Optics Shop (Figure 3). According to Poczulp, the system's vibration insensitivity has exceeded expectations. "We are able to measure at pretty much any time of day, with HVAC equipment running and trucks coming and going at our dock."

For one test, the instrument was moved to an adjacent testing setup to complete optical testing for the One Degree Imager instrument destined for the WIYN telescope. According to Poczulp, the measurements were completed quickly, and the optical testing, a major milestone for the ODI project, was completed on time.

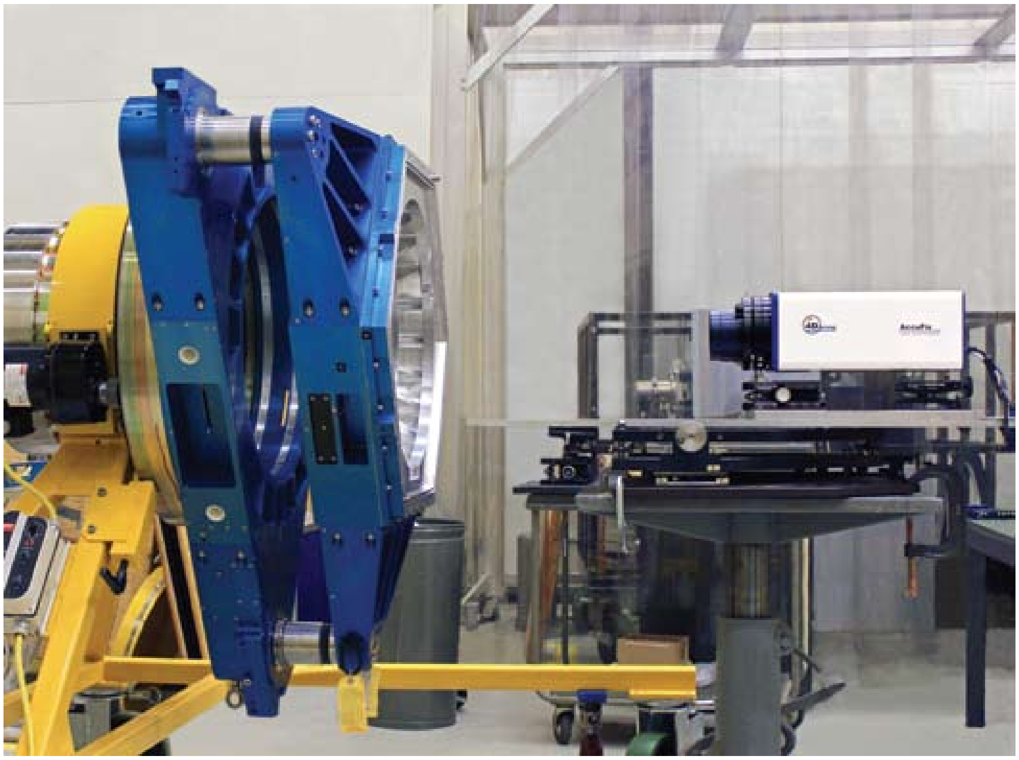

Figure 3. Vibration-Insensitive AccFiz Interferometer at NOAO's Optics Shop facility, shown here measuring components for the WIYN telescope's One Degree Imager.

NOAO is operated by the Association of Universities for Research in Astronomy (AURA Inc.), under Cooperative Agreement with the National Science Foundation.

4D Technology Corporation develops and manufactures optical metrology instruments for applications in astronomy, aerospace, general optics and other industries.

REFERENCES

1. "Analysis of Streetcar Noise and Vibration in NOAO Laboratories" ATS Memorandum, April 7, 2011.