A new large-format, near-IR imaging spectrograph offers a large field of view for monitoring transient astronomical events such as supernovae and gamma ray bursts.

Near-IR astronomical instrumentation is essential for the study of the distant universe. The finite speed of light enables astronomers to investigate the evolution of the universe by comparing the properties of galaxies far away to those found nearby. However, the ongoing expansion of the universe means that light emitted by stars and gas at optical wavelengths will be stretched or ‘redshifted’ to IR wavelengths by the time it reaches Earth. IR instruments also allow astronomers to characterize regions of star formation that are obscured at optical wavelengths by the gas and dust from which they form. The development of large-format, near-IR arrays has enabled the design and construction of a new generation of IR instruments for astronomical research.\(^1\) These arrays are now found in both the largest ground-based and space-based telescopes, as well as smaller instruments. They are often used in wide-field survey programs and in the study of time-variable, synoptic research programs.

Some rare and transient events like gamma ray bursts have relatively poor positional determinations and fade rapidly. It is essential that follow-up imaging at optical and IR wavelengths be obtained as rapidly as possible so that these objects can be more precisely localized. To accomplish this, we are developing the Near-IR Imaging Spectrograph (NIIS). The wide field of view of NIIS and its IR imaging capability will enable rapid characterization of the most distant and highly redshifted examples of these objects. NIIS was designed for wide-field imaging surveys on mid-sized astronomical telescopes and was recently commissioned at the Apache Point Observatory’s 3.5m telescope near Alamogordo, New Mexico.\(^2\)

The optical design of NIIS features a traditional corrector + collimator + camera configuration that allows the images from the telescope that are limited by atmospheric turbulence to be reduced to better match the pixels of the 2048 × 2048 Hawai’i2 detector and produce the widest practical field of view (see Figure 1). The mechanical design features a large optical bench supporting the lens stacks and incorporates a liquid nitrogen tank for cooling the internal components to cryogenic temperatures. A filter wheel and the detector module complete the cryo-mechanical components of the instrument. Cryogenic stepper motors are used for both internal focusing of the detector and for turning the filter wheel. The assembly is supported within a vacuum dewar using a G-10 fiberglass support structure. The entire instrument is approximately 2.1m long, 0.8m in diameter, and weighs approximately 454kg. When attached to the telescope, the instrument is supported on a tubular steel frame.

The lenses for NIIS were manufactured by Optical Solutions Inc. (OSI). The high-precision diamond turning and alignment capabilities at OSI allowed us to design novel lens mounts that maintain the optical alignment of each lens from room temperature down to the cryogenic temperatures at which NIIS operates. The large difference in the thermal expansion coefficients of the

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crystalline optical materials used in NIIS (CaF$_2$, BaF$_2$, ZnSe, and the aluminum of the lens mounts) requires a design that minimizes the potential for damaging the lenses. We developed a design in which a diamond-turned taper on the outer diameter of each lens precisely locates the lens within the lens mount. A spring-loaded retaining ring holds the lens within its mount as both contract and allows only an axial displacement of the lens. The lens mounts are coated in tufram, a hard but low-friction coating that minimizes the friction between the lens and its mount while allowing the lens to be precisely located in its mount. Each lens mount also ‘floats’ within its lens stack, with radial support being supplied only by the friction between the mount and the lens spacer tubes supplied by axial compression of the stack using flanges and spring washers. Figure 2 shows the design of one of the lens mounts. A thermal model of the lens stacks was used to predict the position of each lens at cryogenic temperature. This design also ensures that the radial position tolerance of each lens (typically 10µm) is maintained as the internal components contract during cool-down. Further details regarding the design and performance of NIIS can be found on the instrument’s web page.\textsuperscript{3,4}

The electronics of NIIS consist of a stepper motor controller and a temperature controller for maintaining the temperature of the detector array. The detector array is read out using a programable array controller and preamps built by IR Laboratories and Astronomical Research Cameras Inc. The controller provides the clocking signals to the detector array, digitizes the 32 outputs from the array, and multiplexes these onto an optical fiber connected to the instrument computer. All of the instrument electronics are located outside the instrument with connections into the cryostat provided by hermetic connectors. The instrument is monitored and controlled via a custom interface we wrote in Labview.

Laboratory testing and the on-sky commissioning of NIIS indicate that the lens mount design has maintained the alignment of its optical components. Figure 3 shows an image of a young star cluster (NGC 1977) obtained with NIIS on the APO 3.5m telescope during commissioning in March 2012. The image spans approximately 13 arc minutes on the sky, or about half the apparent size of the full moon. This is one of the largest fields of view for an astronomical IR camera to date and makes NIIS an ideal instrument for near-IR surveys and follow-up of transient.

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astronomical events such as supernovae and gamma ray bursts. In the future NIIS will get a spectroscopic upgrade, which will allow simultaneous, multi-object spectroscopy of as many as 100 astronomical sources. NIIS has one of the widest fields of view of any IR camera to date and will enable astronomical research on a wide range of projects.

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References