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Keo *Sentinel* Wide-Angle Monochromatic Imager

Keo Sentinel Specifications Sheet

The Keo Sentinel is a highly custom designed scientific camera with an wideangle field of view, for studying sub visual emissions from upper atmosphere though a narrow-band filter. The final sensor is a large-formal 2048 x 2048 pixels Charge-Couple Device (CCD). The imager is designed, manufactured, assembled, aligned, and tested at Keo Scientific's laboratory and clean-room facilities in Calgary, Alberta. Canada.

Optics

- Field of View: 150 degrees (wide angle primary lens)
- Angular resolution: 0.1 deg center, 0.5 deg edge of field
- Spatial resolution: 0.5 km at 220 km alt. (zenith)
- Focal length for primary image at filter: 37 mm
- Optics: f/4 telecentric at filter, f/0.95 onto CCD
- Optional protective front shutter (rated for >1 million operations), in custom housing.

Filter

- Imaging Quality Interference Filter, custom manufactured for actual F-cone
- Filter center wavelength: 630.0 nm
- Filter bandwidth: 2 nm FWHM
- Filter transmission at CWL: better than 70%
- Out-of-band blocking: OD 5.0
- Filter diameter: 3 inches
- Filter thickness: 0.25 inches
- "Easy-Change" single-filter cell for narrow-band interference filter

Sensor Head

- Atik 4000 Monochrome Large Format Cooled CCD Camera
- ***CCD camera housing (including mechanical Flange Focal Distance) mechanically custom modified to accommodate Keo Sentinel optics***
- Circular sky image fully inscribed onto CCD's active imaging area
- Kodak KAI 04022 CCD
- 16.7 mm x 16.1 mm (2048 x 2048 pixels) CCD
- Square pixels 7.4 um x 7.4 um.
- Plxel QE: 55% at H-Beta, 50% @ 557.7 nm, 35% at 630.0 nm
- Readout noise: 11 electrons (typ.)
- Dark current: 0.01 electrons (-20 deg C)
- Full Well Capacity: 40,000 electrons
- Exposure time: 1 ms to greater than 10 minutes
- Two stage Peltier with ΔT=-40°C, with optional water assist
- Full temperature regulation
- 16 bit ADC
- USB2 Interface
- 12 VDC operation (110/220VAC power supply included)

Environmental

- +4 C to +25C, non condensing
- Filter cell not thermally controlled, so we recommend an ambient temperature of 20 deg C (+/- 5 deg C)
- Instrument mass: 6.8 kg (all optics and integrated sensor head)
- Physical Size: 630 mm long, 75 mm diameter optical tubes, CCD camera 125 mm x 125 mm wide
- Mounting: 4 x helicoiled 1/4 x 20 mounting holes provided

Electronics and Control

- Computer requirements: Shutter operation (optional), CCD gain/binning, image acquisition is managed from any computer via USB2 interfaces
- All required cables provided
- All power supplies and control electronics are included.
- Voltage requirements: 110 or 220 VAC (50 or 60 Hz)
- Power Consumption: 0.6A @ 12 VDC

Calibration

- Full absolute calibration available at extra cost (maps raw pixel values to rayleigh intensity)

About Keo Scientific Low Light Level Monochromatic Imagers

The maximum throughput of any optical system designed for low-light-level monochromatic imaging of aurora/airglow is determined by the F-number of the primary optics and maximum practical filter size. The main contribution to noise is the airglow continuum background, which can be minimized by reducing filter bandwidth. The main objective of maximizing signal-to-noise ratio (SNR) requires consideration of both these aspects.

If the input optics is designed to be telecentric on the image side, then the maximum ray angle through the filter is determined by the F-number of the lens. The wavelength of peak transmission of interference filters decreases with ray angle, so to accommodate larger cone angles through the filter requires increased filter bandwidth. Thus there is a tradeoff between throughput (increases with decreasing F number) and background noise which is proportional to filter bandwidth (which must increase with decreasing F number).

In our extensive experience, we have found the best combination of primary lenses, largest practical filter diameter, and best compromise of filter bandwidth/system F number, is as follows:

- **Filter diameter:** 3” (75mm)
- **Filter Bandwidth:** 2.0 nm
- **Primary Lens F number:** 4.0 (7 deg. half-cone angle)
- **Lens Type:** Medium format (required so image size fills large filter)

For example, for all-sky monochromatic imaging, we use a F4.0 primary lens. Keo supplementary optics is used to give telecentricity on the image side, and the filter is placed near the primary image plane. This image is then re-imaged onto the detector at f/095 Keo-designed achromatic re-imaging optics.

The re-imaging optics may be chosen to match the final detector size, typically in the range of 12-25mm. Care must be taken that all of the light collected by the primary optics is then imaged onto the (smaller) detector. This requires that the Lagrange Invariant $\alpha \times d$ is conserved (where α is the cone angle, and d the image size).