different between channels, and the intrinsic resolution of the two detectors differs – which means that even two channels with identical designs can have substantially different resolving powers at the same wavelength.

The apertures in the FPAs include a narrow 1.25" × 20" slit (HIRS) for maximum resolution, an intermediate 4" × 20" (MDRS), and a large 30" × 30" (LWRS) for maximum throughput. The FPAs can be adjusted in the dispersion direction in order to coalign the four channels, and in the focus direction to maintain spectrograph focus. In addition, the telescope mirrors can be adjusted in focus, tip, and tilt in order to maintain coalignment and focus the mirrors to the FPAs; the gratings and detectors are fixed on orbit. The satellite pointing is adjusted in order to select a particular aperture once the channels are aligned using the mirrors and FPAs. A visible-light Fine Error Sensor (FES), which views the FPA on one of the LiF channels, is used to maintain pointing using stars within a 20' × 20' field around the target.

The two FUSE detectors are windowless, multi-segment, large format, two dimensional microchannel plate (MCP) detectors with helical double delay line (DDL) anodes. A detector consists of two segments, each with an active area of 88 × 10 mm; these segments are separated by a gap of < 10 mm. The front surface of each MCP is coated with a KBr photocathode in order to maximize the far ultraviolet response. Quantum efficiencies are in the range of 14 – 30% in the FUSE bandpass, depending on the segment and the wavelength range. On orbit, a mechanical door which protected the photocathode during ground testing and launch was opened once the spectrograph cavity pressure reached an acceptable level. Ion pumps were then used to monitor the pressure in the spectrograph cavity until it dropped low enough for high voltage operations to begin. High voltage operations of the two detectors began in mid to late August, 1999. Details of the design of the FUSE detectors has been given elsewhere[5].

The size and location of pixels in DDL detectors are not fixed, but are determined by timing and analog measurements. The detector pixels are digitized to approximately 6 µm (~6 mÅ) in the dispersion direction, and 10 – 17 µm (depending on segment) in the cross dispersion direction, for a full extent of 16384 × 1024 pixels. The intrinsic detector resolution, however, due to the MCP pore size and spacing of 10 – 15 µm and the design of the electronics, is limited to ~20 µm × ~80 µm FWHM.

Data collected by the detectors is sent via the science data bus to the Instrument Data System (IDS). The IDS is responsible for storing this data as individual photon events (time tag or TTAG mode) with periodic time markers (typically once per second), or assembling the data into a two-dimensional histogram (spectral image or HIST mode). Targets with a total count rate less than ~2,000 cps are taken in time tag mode in order to preserve information on the arrival time of the photons. At higher count rates (up to ~32,000 cps), the onboard memory would be quickly exhausted, so the data from only the relevant part of the detector is binned (typically by 8) in the y direction and stored as a two-dimensional image. Since the arrival times of the individual photons are lost in this process, Doppler corrections for the orbital velocity can only be made on the image as a whole; as a result, each observation is divided into multiple exposures during each orbit. The y binning has a negligible effect on the resolution of the data.

The FUSE spacecraft bus, built by Orbital Sciences Corporation and located below the instrument section, consists of the power, attitude control, and communications systems for the satellite. The instrument and spacecraft together make up the FUSE satellite.

Operations are controlled from a Satellite Control Center (SCC) at the Johns Hopkins University. Operations are described in section 7.1.

3. DETECTOR PERFORMANCE

3.1. Flat Field and Signal to Noise

An onboard mercury-vapor stimulation lamp permits a roughly uniform illumination of each detector. Because of count rate limitations of the detector electronics, however, it is not practical to take deep flat fields on orbit; in addition, grid wires from the detector's ion repeller and plasma grids shadow parts of the detector when illuminating the detector this way. Before launch, flat field images were taken with a diffuser in front of the detector in order to minimize the effect of the grid wires. These flat fields contain 40 – 100 events per pixel, which is sufficient to obtain a signal-to-noise ratio of 50 – 120 per a spectrograph resolution element of 6 pixels in the x direction and 7 – 70 pixels in the y dimension (depending on wavelength and channel). It had been expected that the much lower signal-to-noise stim lamp exposures could then be used to transform the ground based