# TS2 dispersers advisory

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**Summary**

The TS2 spectrum is positioned horizontally on the CCD by rotating the echelle grating, and vertically by rotating the prism assembly. The motion control mechanical, electronic, and software systems for the two rotations were replaced in March 2023. The encoders of the prism and echelle positions have been changed from relative to absolute encoders. As a result, the encoder values no longer change due to mechanical slippage. The encoding and drive mechanism resolutions have increased 25-to-50 times. Encoder values for the Prism and Echelle positions from the last 30 years are no longer valid. Updated spectrum positioning scripts are available.

**The new TS2 disperser subsystems**

The new disperser motion control is composed of these subsystems

- two absolute encoders, that directly measure the position of the prisms, and of the echelle grating
- the prism drive mechanism, that has been fully replaced
- the echelle drive mechanism, that has been 75% replaced. The previous drive roller system and gear box have been retained
- a modified GUI interface (figure 1), running from modified TS server software (note figure 4)

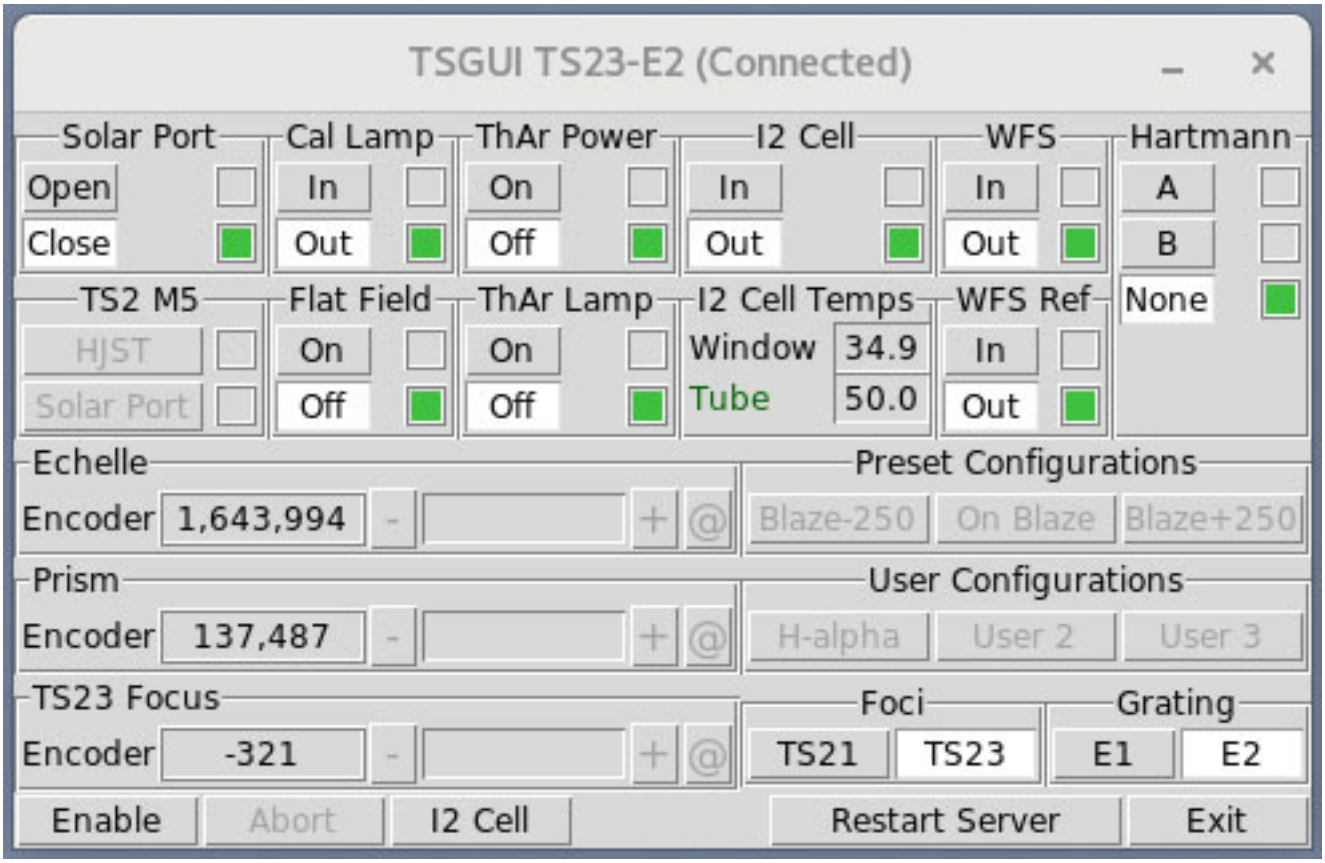


**Figure 1:** the TS GUI is shown with motion disabled (the *Enable* button not pressed). This is the normal state of the GUI during observing.

**Quick start notes (for TS23)**

- There are now three primary modes of operation for configuring the TS2 dispersers
    - *'Manually'* moving the dispersers by entering echelle and prism encoder values in the GUI. This can also be done from the ICE command line. Over time, the reproducibility of positioning the spectrum on the CCD will be good to about 1 or 2 pixels
    - Using new GUI *Preset Configurations* or *User Configurations*. Over time, the reproducibility of positioning the spectrum on the CCD will be good to about 1 or 2 pixels
    - Using the ICE script *ts2cfg* to position a current ThAr spectrum relative to a reference ThAr spectrum to a precision of better than 0.1 pixels. This typically takes 2-3 minutes.
- the ICE script ts23cfg has been replaced by ts2cfg. The new script configures the instrument and does a series of validity checks. The script works for TS21, TS23, E1, E2, and binnings that are valid for the combinations of TS2x-Ey. See the later section on ts2cfg.
- The echelle
    - Increasing the echelle encoder value increases the wavelength at the center of the CCD within each diffraction order. That is, the spectrum moves to the left as normally displayed by ds9
    - A positive O-C error between a current spectrum and a reference spectrum is corrected by a positive change in the echelle encoder value
    - The spectrum moves 1 pixel per 25 encoder units for TS23 using TK3 and E2 (see tables 1 & 2)
- The prisms
    - Increasing the prism encoder value increases the wavelength of the order across the center of the CCD. That is, the spectrum moves up the screen as normally displayed by ds9
    - A positive O-C error between a current spectrum and a reference spectrum is corrected by a negative change in the prism encoder value
    - The spectrum moves 1 pixel per 50 encoder units for TS23 using TK3 and E2 (see tables 1 & 2)
- Moving the Prisms and the Echelle
    - The *Enable* button must be pressed to allow motion, as is also the case for the focus motion
    - *Unsigned* numbers can be entered in the data entry boxes beside the encoder values. Pressing the '-' button moves negative *relative* to the current position by the entered amount. Pressing '+' moves positive *relative* to the current position. Pressing '@' moves to the *absolute* position entered. The '-' or '+' buttons turn red if the forward or reverse motion limits are reached.
    - When the motion axis is moving, the encoder value turns *Red*. Observations should not be taken when an axis is moving. Please see figure 2 for an example of the system in motion.
- Preset disperser positions
    - There are 3 buttons on the GUI that configure the dispersers to preset useful positions. These will normally reposition the spectrum to within a pixel or so on the CCD. See a later section for details. Motion must be *Enabled* to make these buttons active
- User configurations
    - There are 3 buttons that can be programed by the user to allow quick changes to different configurations of the dispersers. These will normally reposition the spectrum to within a pixel or so on the CCD. See a later section for details. Motion must be *Enabled* to make these buttons active
    - The information for each User button is read from a file in the users account, including the name for the button, the echelle encoder value, and the prism encoder value. See a later section for details
    - The user buttons are of particular use for TS21 observers who move the spectrum significantly between multiple configurations

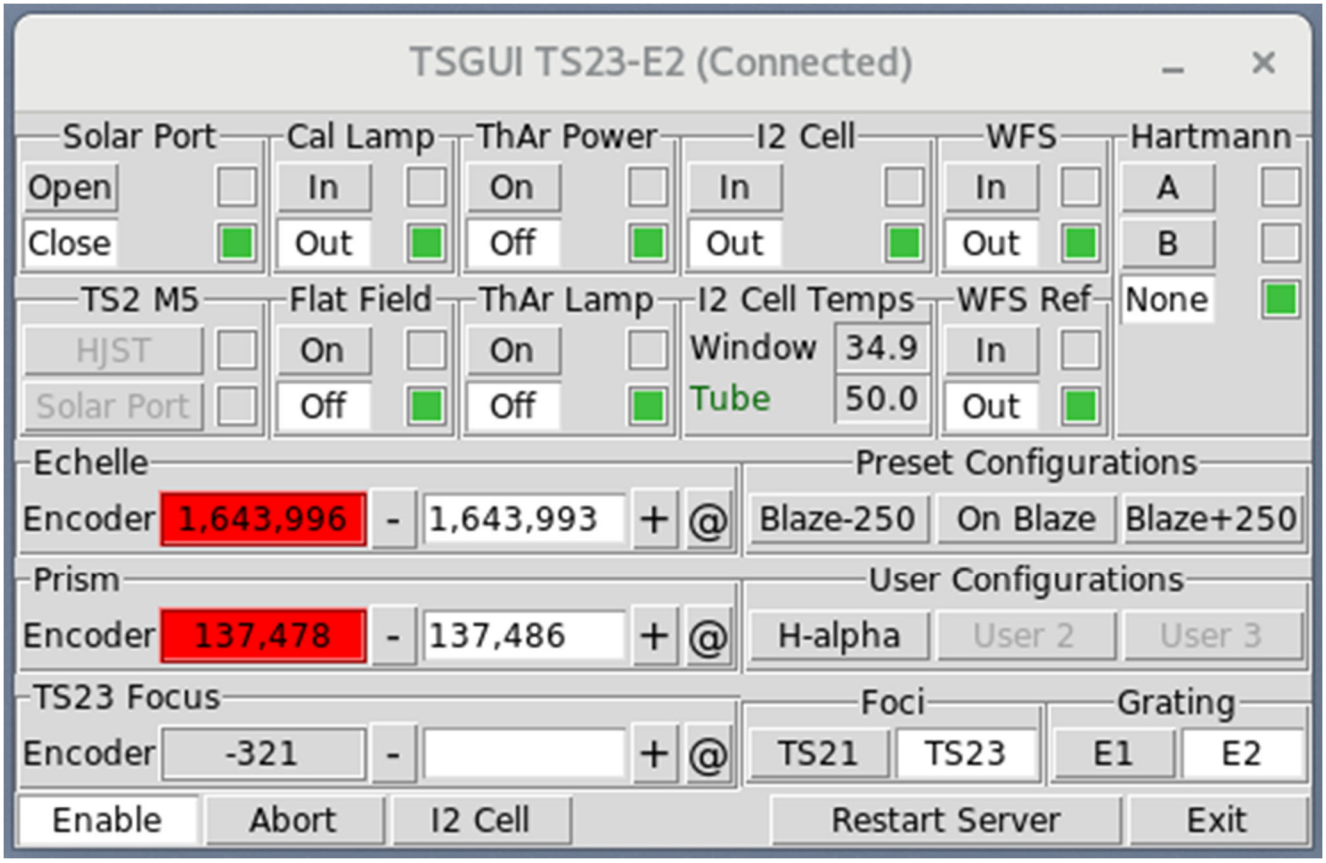


**Figure 2:** the GUI with motion enabled. Final required encoder values for the echelle and prisms have been entered and the '@' buttons have been pressed. Motion is in progress and so the encoder values are red. This same behavior is seen when the Preset or User Configuration buttons are used

**Instrument *Drift:***

The encoder values will be seen to change a few counts in various scenarios, for various reasons. At the time of writing work continues to optimize the performance. Here is some background information

- **Air temperature and Pressure**: the refractive index of air changes with temperature and pressure, and this causes small shifts in the spectrum on the CCD. Also, the temperature of the prisms changes their refractive index and moves the spectrum vertically on the CCD. There are seasonal changes in the exact position of the spectrum when using the Preset buttons, with shifts of up to ~10 pixels. Future software versions will correct for these shifts
- **Mechanical issues:** the disperser assembly weighs nearly 1000 kg, and it is being positioned to about 0.1 arcseconds around each of its two rotational axes. For the prisms it's 0.07 arcsec per encoder unit, and for the echelle it's 0.15 arcsec per encoder unit. One encoder unit is a linear motion in the corresponding drive mechanism of 244 nm. All drive mechanisms have a characteristic stiffness, from behaviors such as torsional *windup* in gearboxes. Large moves, primarily for the echelle, will show some drift after the move completes due to the windup relaxing. *Repeating* the move after a large move will result in a very small move, and that will help relax the drive mechanism and reduce creep
- **Detector remounts:** between TS2 observing runs detector TK3 may be dismounted and remounted. This may result in shifts of the spectrum on the CCD, for given echelle and prism values, of a few pixels

## Preset Configurations

Figure 2 illustrates the 3 Preset Configurations for TS23-E2. The *Preset Configurations* change for each *Focus* and *Grating*. Currently there is 1 preset that applies to Focus *TS21* and both echelle gratings, as shown in figure 3. Observers are welcome to recommend spectral regions for the two unused TS21 presets. The current Preset Configurations for TS23-E2 (first 3) and TS21-En (E Change) are

- **On Blaze:** this puts the centers of the orders (the blaze peaks) on the central column of the CCD. It also positions the spectrum vertically to cover orders from 350 to 1050 nm. When this button requires a large move, the button might need a second pressing for a more accurate and stable reconfiguration. This configuration is sometimes called the MOPS configuration (McDonald Observatory Planet Search).
- **Blaze-250:** the position in the orders 250 pixels blue of the order blaze peaks is positioned on the central column of the CCD. It also positions the spectrum vertically to cover orders from 350 to 1050 nm. When this button requires a large move, the button might need a second pressing for a more accurate and stable reconfiguration. Figure 5 shows a trace along raw data in the order with H-alpha. The core of H-alpha is on column 170, about 425 km/s from the blue edge of the CCD. The Free Spectral Range of the orders is wider than the CCD for orders red of 590 nm. This setting allows the blue ends of the red and NIR orders to be observed. For example, it moves H-alpha onto the CCD.
- **Blaze+250:** the position in the orders 250 pixels red of the order blaze peaks is positioned on the central column of the CCD. It also positions the spectrum vertically to cover orders from 350 to 1050 nm. When this button requires a large move, the button might need a second pressing for a more accurate and stable reconfiguration. The Free Spectral Range of the orders is wider than the CCD for orders red of 590 nm. This setting allows the red ends of the red and NIR orders to be observed.
- **E Change**: this is for use by Observing Support only. It rotates the echelle grating to the position that is safest for changing the grating. This may be moved from a *Preset* to an OS *User Configuration* button.

## User Configurations

Figure 3 illustrates 3 *User Configurations* in use for TS21 with E2. These configurations are read from the file *tsgui.cfg*. When using the *Launcher* to start *tsgui*, the file *tsgui.cfg* must be in the user's home directory (~<user name>). When starting tsgui from the command line, file *tsgui.*cfg must be in the directory in which *tsgui* is started. An example of the file format follows, used for figures 1, 2, and 3.

```
ts21-e1,user1=
ts21-e1,user2=
ts21-e1,user3=
ts21-e2,user1=Ba 4554,1644000,122000
ts21-e2,user2=Li 6707,1624000,147000
ts21-e2,user3=Rb 7889,1644000,157000
ts23-e1,user1=
ts23-e1,user2=
ts23-e1,user3=
ts23-e2,user1=H-alpha,1638836,137486
ts23-e2,user2=
ts23-e2,user3=
```

There are 4 groups of 3 lines, 1 group for each of the combinations of TS2x and Ey. After the "=" sign the 3 comma-separated parameters are 1) the button name, that can include spaces, 2) the encoder position for the echelle, and 3) the encoder position for the prisms. Note that the numbers in the ts21 buttons are approximate example values. That is, they are rough guesses. Unused buttons need not be included in the file.

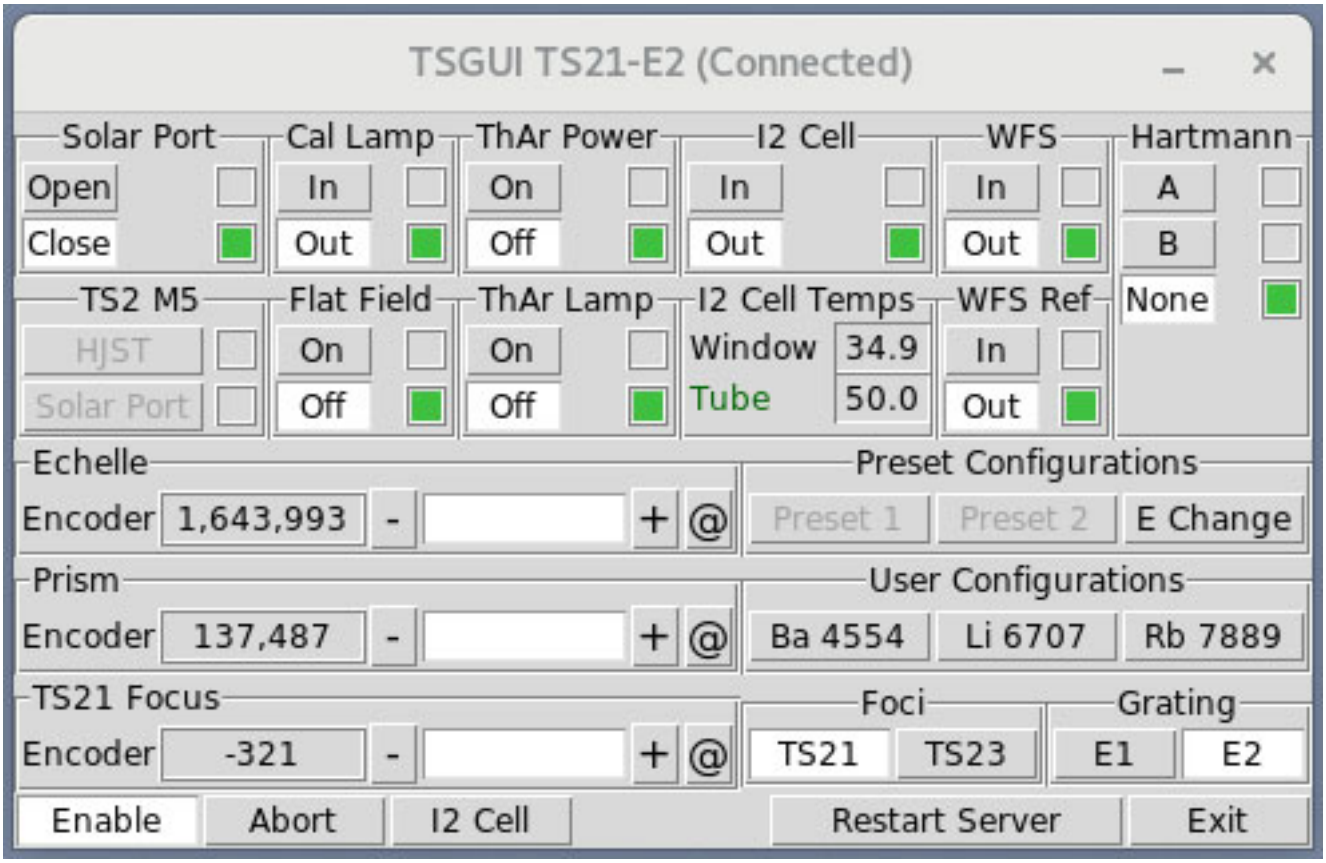


**Figure 3:** the GUI with user specified configurations of the dispersers attached to each of the 3 buttons in the *User Configurations* section of the GUI. The choice of what is attached to the buttons is dependent upon the selections from the *Foci* and *Grating* button groups.

**ICE script ts2cfg**

Before the upgrade, ICE script ts23cfg was in use to accurately reconfigure the echelle and prisms so that a current ThAr image matches a previous reference ThAr image. That script only worked for TS23 with E2 and 1x1 binning. The new script *ts2cfg* works for TS21, TS23, E1, E2, and the valid CCD binnings for the TS2x-Ey.

Getting the new script:

- The new script /home/hjst/ice_scripts/ts2cfg.cl should be copied to your ice/scripts directory
- edit your myscripts.cl file in ice/scripts to change ts23cfg to ts2cfg in both places
- when first running ICE, use the command: unlearn ts2cfg
- while running ICE, check out the ts2cfg default values using the command: epar ts2cfg

A fresh copy of ts2cfg points to a reference ThAr image, located in a system repository, for the *On Blaze* configuration of TS23-E2. A user can set the path to their own reference images, and specify the reference image to be used on the next invocation of ts2cfg. References in the system repository will be maintained.

So long as the slit cover and instrument covers are open, and the instrument is running, the script should take 2-to-3 minutes without further interacton to configure the echelle and prisms for TS23 to within 0.1 pixels of a previous configuration, and to within 0.25 pixels for TS21. Some users might choose to just enter previous echelle and prism encoder values, or use Preset or User configuration buttons. These choices should yield 1 to 1.5 pixel repeatability over all weather conditions.

### Updating prevous ts23cfg reference images

Reference ThAr images taken with the original disperser control hardware do not work with *ts2cfg*, nor with the previous sript *ts23cfg*. It is a fairly quick and easy task to modify the headers of an existing reference image so that the image is valid for *ts2cfg*. It is not recommended that replacement reference images be made as there will almost certainly be some degree of shift between new and original images.

Currently, please e-mail pjm@astro.as.utexas.edu with file name(s) and file location(s) of your reference image(s), and Phllip MacQueen will update your images (easiest option). Alternatively, give Phillip a call at (512) 672-9445 and he'll talk you through it. A written procedure may be produced in a future version of this document.

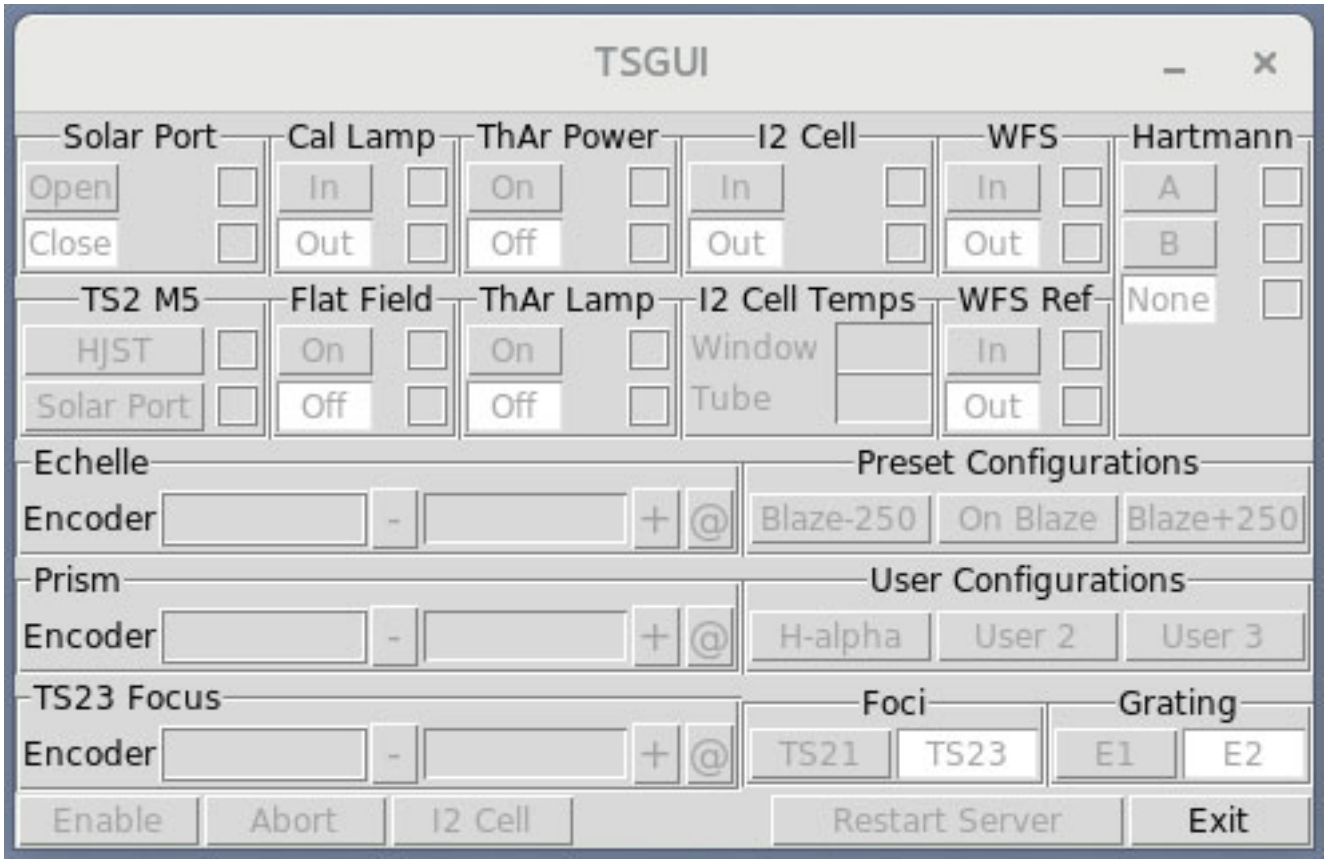


**Figure 4:** The TS software is organized in a server-client architecture. The server, called *tsserver*, runs on computer atlas in the background and is the only piece of software that communiates with the spectrograph control system. Clients, including the TS GUI and ICE, request actions and information from the server. When the server is not running the GUI presents in the blank state shown.

| Echelle name | Binning | TS21 | | TS23 | |
|---|---|---|---|---|---|
| | | ΔEchelle per pixel | ΔPrisms per pixel | ΔEchelle encoder | ΔPrisms encoder |
| E1 | 1x | 5.79 | -11.69 | -24.79 | 50.00 |
| | 2x | 11.59 | -23.37(1) | - | - |
| E2 | 1x | 5.84 | -11.69 | -25.00 | 50.00 |
| | 2x | 11.69 | -23.37(1) | - | - |

**Table 1:** when using CCD **TK3** (24 micron pixels), the required changes in the echelle and prism encoder values are tabulated for making +1 pixel horizontal and vertical shifts in the spectrum, respectively. The shifts are a function of TS2 focus (the TS2x), echelle grating (the Ey), CCD column binning for the echelle dispersion (horizontal axis of an image), and CCD row binning for the prism dispersion (vertical axis of an image). For example, if TS21-E1 is being used with 2x column binning, and 1x row binning, a +1 pixel horizontal shift in the image requires a change in the echelle encoder value of +11.59 EUs (EU = Encoder Unit), and a +1 pixel vertical shift in the image requires a change in the prism encoder value of -11.69 EUs.
(1) 3x and 4x row binning are also valid, with values of 35.06 and 46.74 EU per pixel, respectively

| Echelle name | Binning | TS21 | | TS23 | |
|---|---|---|---|---|---|
| | | ΔEchelle per pixel | ΔPrisms per pixel | ΔEchelle encoder | ΔPrisms encoder |
| E1 | 1x | 3.62 | -7.30 | -15.50 | 31.25 |
| | 2x | 7.24 | -14.61(1) | -30.99(2) | 62.50 |
| E2 | 1x | 3.65 | -7.30 | -15.63 | 31.25 |
| | 2x | 7.30 | -14.61(1) | -31.25(2) | 62.50 |

**Table 2:** when using CCD **EV2** (15 micron pixels), the required changes in the echelle and prism encoder values are tabulated for making +1 pixel horizontal and vertical shifts in the spectrum, respectively. The shifts are a function of TS2 focus (the TS2x), echelle grating (the Ey), CCD column binning for the echelle dispersion (horizontal axis of an image), and CCD row binning for the prism dispersion (vertical axis of an image). For example, if TS21-E1 is being used with 2x column binning, and 1x row binning, a +1 pixel horizontal shift in the image requires a change in the echelle encoder value of +7.24 EUs, and a +1 pixel vertical shift in the image requires a change in the prism encoder value of -7.30 EUs.
(1) 3x and 4x row binning are also valid, with values of 21.91 and 29.21 EU per pixel, respectively
(2) 2x column binning is only valid for slit #5 yielding R=45,000. With this slit and CCD the resolution element is 4.80 unbinned pixels, allows 2x binning to produce a 2.40 pixels per resolution element, which is greater than the Nuquist sampling limit of at least 2 pixels per resolution element.

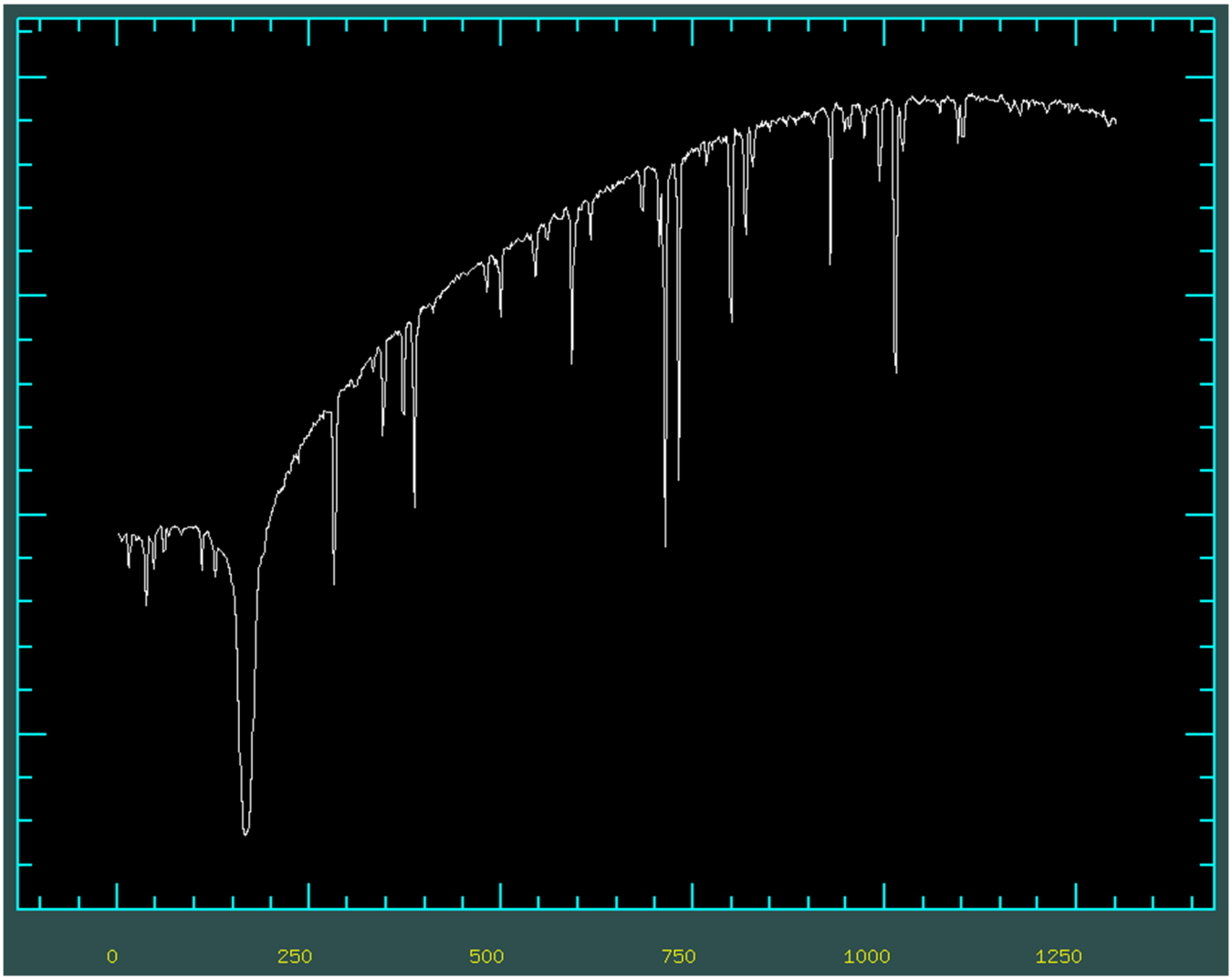


**Figure 5:** The blue end of the 'H-alpha' order, observed with TS23-E2. The configuration was set with the GUI preset button *Blaze-250*. This is a trace along the part of the order from CCD column 1 to column 1300 in a Solar Port spectrum with slit #4. The core of H-alpha is on column 170, about 425 km/s from the blue edge of the CCD.