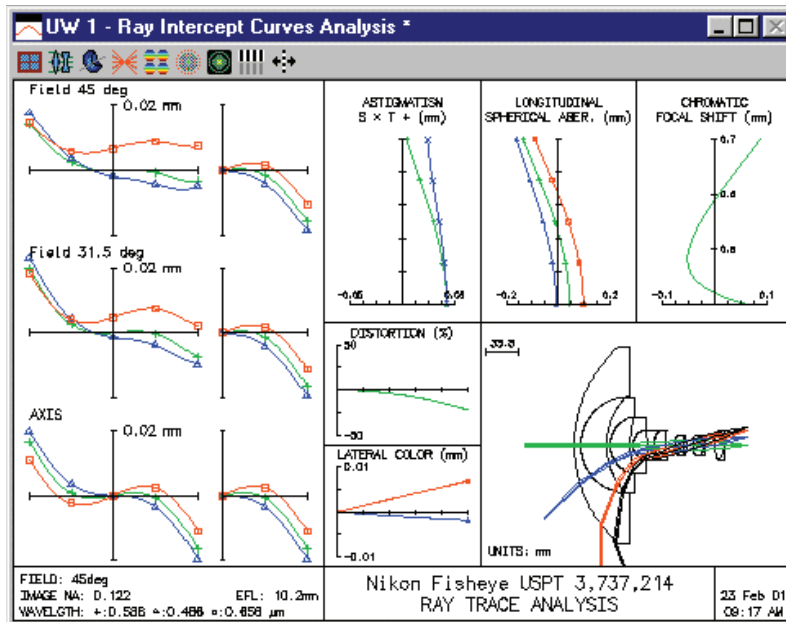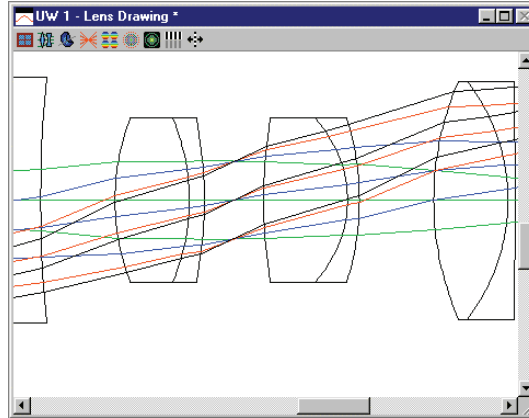# *Fisheye lens*

Lenses that have fields of view of greater than 90 degrees (half-angle) require special attention in setup, since the conventional methods for specifying field of view are awkward to handle for this case. In addition, special care must be taken within the ray trace routines to ensure stability. Finally, care must be taken in evaluating such lenses, since many of the built-in evaluation procedures (e.g. report graphics) implicitly assume a field of view of less than 90 degrees. The nikofish.len file is an example of such a lens. It is based on a Nikon patent, and is implemented here as a 10mm efl lens that covers a field of view of 108 degrees with an aperture of f/4.

As you can see from the drawing, the aperture stop of the lens is well back in the lens, on surface 14. Obviously the pupil position is a function of the field angle, moving almost to the first surface at the edge of the field. In order to accommodate this type of system and ensure that the rays pass through the desired positions on the aperture stop, OSLO uses the **warm** (wide-angle ray-aiming mode) general operating condition.
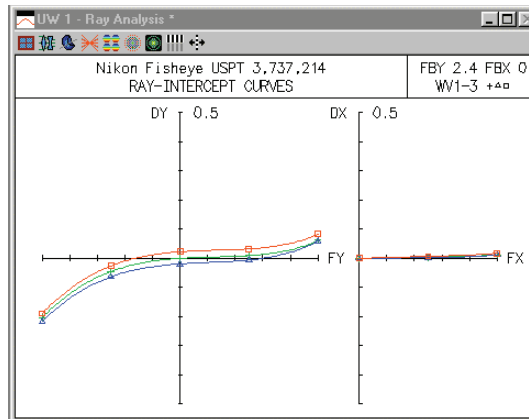
When **warm** is on, fractional object coordinates (for infinite conjugate systems) represent angles in degrees, relative to the nominal field angle of the system. For the present system, the field angle is specified as 45 degrees, so a fractional object height of 1.0 refers to a point 45 degrees off axis. The edge of the field of view of this system occurs at a fractional object height of 2.4.

In addition, when **warm** is on, fractional pupil coordinates refer to positions in the reference surface, normalized to the reference surface radius (not the entrance beam radius). For the nikofish lens, the reference surface (aperture stop) radius is 5.2 mm, so a fractional aperture coordinate FY = 0.5 refers to a point in the aperture stop 2.6 mm from the optical axis. The figure below shows a zoomed drawing of the lens near the stop surface. You can see that the rays always go through their prescribed points in the aperture stop. In this connection, it should be mentioned that it is not necessary to have **warm** on to have the chief ray go through the center of the stop: this always happens (unless the ray trace fails for some reason). The **warm** condition only affects ordinary rays.

To evaluate fisheye systems, you can use all the routines that use the current field point, which can be set to a value greater than 1.0 using the **sop** command. For example, a ray intercept curve at the edge of the field of view can be obtained as follows:

```
*SET OBJECT POINT
        FBY          FBX          FBZ
     2.400000        --           --
        FYRF         FXRF         FY           FX
        --           --           --           --
        YC           XC           YFS          XFS          OPL       REF SPH RAD
     18.702850       --        0.219863     0.062672    182.326549   Infinite
```


There is some problem in obtaining a graphical field analysis, because all the internal routines extend only to FBY = 1.0. However, the star command *field accommodates two arguments that give the number of field points and the maximum fby, respectively. The command ***field 12 2.4** produces the following output.

```
*FIELD ANALYSIS
 WAVELENGTH 1
      FIELD         YC           YFS          XFS          % DIST      LAT COLOR
      --            --         0.042414     0.042414        --           --
   0.200000      1.606980     0.040257     0.041150     -0.858303    -0.001824
   0.400000      3.210651     0.034107     0.037644     -3.444843    -0.003608
   0.600000      4.807926     0.024917     0.032730     -7.795877    -0.005325
   0.800000      6.396158     0.014212     0.027698    -13.976597    -0.006981
   1.000000      7.973349     0.004033     0.024151    -22.088918    -0.008626
   1.200000      9.538334    -0.003140     0.023787    -32.283884    -0.010379
   1.400000     11.090926    -0.004421     0.028098    -44.780543    -0.012438
   1.600000     12.631948     0.003501     0.037920    -59.894417    -0.015109
   1.800000     14.163058     0.024490     0.052703    -78.080634    -0.018818
   2.000000     15.686059    -0.177583     0.069185   -100.000000    -0.024115
   2.200000     17.201146     0.125809     0.078828   -126.621245    -0.031608
   2.400000     18.702850     0.219863     0.062672   -159.380288    -0.041751
```

Monochromatic air-spaced doublet

The lasrdblt.len file is designed to focus light (on axis) from a helium-neon laser. You can see from the ray analysis below that the lens far outperforms the Cooke triplet, double Gauss, and