**Summary of our camera for Zemax setup:**

| **Parameter** | **Value** |
| --- | --- |
| Focal Length | 72.8 mm |
| f/# | 1.05 |
| Aperture Diameter | 72.8/1.05 ≈ 69.33 |
| Pixel Pitch | 12 µm |
| Detector Resolution | 640 × 512 |
| Sensor Size | 7.68 mm × 6.144 mm |
| Wavelength Range | 8–14 µm |
| Field of View (H) | 6° |
| Object Distance | Infinity |

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**Step 1: Units Configuration**

The simulation was initiated in **Zemax OpticStudio (Sequential Mode)**. To prepare the system for thermal infrared design (8–14 µm range), all relevant unit settings were configured.

**How to Set These:**

* Navigate to the **System Explorer**
* In the left panel, click on **“Units”**

**Configured Parameters:**

* **Lens Units**: Millimeters
* **Source Unit Prefix**: None
* **Source Unit**: Watts
* **Analysis Unit Prefix**: None
* **Analysis Unit**: Watts per cm²
* **Afocal Mode Units**: Milliradians
* **MTF Units**: Cycles/millimeter
* **CAD Units**: Lens Units

These settings ensure that the system is ready to handle radiometric simulation of the FLIR Boson 640 camera, supporting physical quantities like power (Watts), irradiance (W/cm²), and spatial resolution (cycles/mm). All distances and dimensions are interpreted in millimeters for consistency with lens and sensor data.

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**Step 2: Aperture Settings**

To control the incoming light cone into the optical system, the aperture settings were defined based on the FLIR Boson 640 camera specifications.

How to Set This in Zemax:

* Open System Explorer
* Select “Aperture”

Configured Parameters:

* Aperture Type: Entrance Pupil Diameter
* Aperture Value: 69.33 mm (calculated from focal length and f/#)
* Apodization Type: Uniform
* Fast Semi-Diameters: Enabled ✅

This configuration allows Zemax to properly model the incoming ray cone of an f/1.05 system, crucial for accurate simulation of thermal IR imaging optics with large numerical aperture.

**Wavelength and Field of View Setup**

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**Wavelength Setup**

**Step 3A: Wavelength Configuration**

The spectral range of the FLIR Boson 640 spans 8–14 µm, corresponding to the long-wave infrared (LWIR) region. Zemax requires a set of discrete wavelengths for simulation. The following three wavelengths were chosen:

* 8 µm
* 10 µm (set as the primary wavelength)
* 14 µm

How to Set in Zemax:

* Go to System Explorer
* Select “Wavelengths”
* Add 3 wavelengths: 8, 10, 14
* Set 10 µm as Primary
* Keep weight = 1 for all

This configuration ensures proper simulation across the full operational band of the detector.

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**Step 3B: Field Configuration**

The FLIR Boson 640 has a **6° horizontal field of view**. To simulate image quality across the field, multiple field angles were defined:

* **Field 1**: 0.00° (center)
* **Field 2**: 1.50° (mid-field)
* **Field 3**: 3.00° (edge of FOV)

**📍 How to Set in Zemax:**

* Open **System Explorer**
* Click on **“Fields”**
* Set **Field Type** to **Angle**
* Enter field angles: 0.00, 1.50, and 3.00 degrees
* Keep **weight = 1** for all

These field points allow Zemax to evaluate performance across the entire image area.

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**Image Surface Setup**

**Step 4: Image Plane Configuration**

The image surface was configured to match the physical dimensions of the FLIR Boson 640 thermal infrared detector.

**Detector Specs:**

* **Resolution**: 640 × 512 pixels
* **Pixel Pitch**: 12 µm

Sensor Width=640×0.012=7.68 mm,

Sensor Height=512×0.012=6.144 mm

**Zemax Configuration:**

* The image surface is Surface 2 in the Lens Data Editor.
* In **Surface Properties → Aperture tab**, the **Aperture Type** was changed to **Rectangular Aperture**
* The half-dimensions were set as:
  + **X Half Width** = 3.84 mm
  + **Y Half Width** = 3.07 mm
* Aperture center offsets (**X/Y Decenter**) were set to 0 to keep the surface centered on the optical axis.

This setup ensures that Zemax accurately models the rectangular active area of the detector, enabling precise simulation of spot sizes, field footprints, and overall system performance.

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**Realistic Lens Setup**

**Step 5 – Realistic Infrared Lens System Design**

To simulate the FLIR Boson 640 thermal infrared camera realistically, a physical lens element was added to the Zemax model using an actual infrared-transmitting material. The selected material is Germanium (IR), which is widely used in long-wave infrared (LWIR) systems due to its excellent transmission in the 8–14 µm range.

A plano-convex germanium lens was designed based on the FLIR Boson’s nominal focal length of 72.8 mm. The front curvature was calculated using the Lensmaker’s formula for a thin lens, assuming a refractive index of n ≈ 4.0 at 10 µm. The result yielded a front surface radius of curvature of +218.4 mm, with a flat back surface.

Lens Parameters

* Material: Germanium (IR)
* Front Surface Radius: +218.4 mm
* Back Surface Radius: ∞ (plano)
* Lens Thickness: 5 mm
* Spacing to Image Surface: 72.8 mm (initial focal plane estimate)

Zemax Implementation

* Two lens surfaces were inserted between the stop and the image surface.
* Surface 2 (front of lens): Radius = +218.4 mm, Material = Germanium, Thickness = 5 mm
* Surface 3 (back of lens): Radius = ∞, Material = Air, Thickness = 72.8 mm
* Both surfaces were assigned a semi-diameter of 35 mm, consistent with the system's entrance pupil.

Image Surface Correction

After inserting the lens, Zemax automatically resized the image surface semi-diameter to over 500 mm to include all ray intersections. This value was physically unrealistic for the FLIR Boson sensor. The image surface semi-diameter was manually corrected to 4.0 mm, and the rectangular aperture dimensions were enforced as:

* X Half Width: 3.84 mm
* Y Half Width: 3.07 mm

This correction ensured that rays were evaluated only on the actual active area of the detector, providing more accurate simulations of spot size and irradiance distribution.

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3D optical layout of the simulated FLIR Boson 640 camera in Zemax OpticStudio. Ray bundles from different field angles converge near the image surface.

**Step 6A – Optical System Layout (3D View)**

To visually inspect the geometry and ray behavior of the FLIR Boson 640 camera model, a 3D layout view of the system was generated in Zemax OpticStudio. This layout illustrates how collimated rays from different field angles (0°, 1.5°, 3°) interact with the optical elements and converge at the sensor plane.

The rays enter through a large aperture and pass through a plano-convex **germanium lens**. The convergence point of the rays indicates the location of the image plane, which is positioned based on the expected **focal length of 72.8 mm**. The figure clearly shows:

* A **plano-convex lens geometry**, with the curved surface facing incoming rays
* Proper **ray refraction and convergence**
* A sensor placed near the theoretical focus, where the rays intersect

This view confirms that the lens is actively bending the rays from all fields toward a common focal plane. The visualization also demonstrates the **symmetry and alignment** of the optical system, which is crucial for minimizing off-axis aberrations.

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Spot diagrams at 0°, 1.5°, and 3° for 8 µm, 10 µm, and 14 µm wavelengths. The current optical configuration produces large spot sizes, indicating that the image plane is out of focus.

**Step 6B – Spot Diagram Analysis**

Spot diagrams were analyzed at 0°, 1.5°, and 3° field angles for three wavelengths (8 µm, 10 µm, and 14 µm). Each plot shows the distribution of rays on the image plane relative to the ideal focus.

The results show that the system is currently **severely defocused**, with **RMS spot radii ranging from ~1970 µm to 2228 µm**, compared to the detector pixel size of **12 µm**. This confirms that the **sensor is not located at the correct back focal distance**. A refocusing operation will be performed in the next step to bring the image plane into alignment with the actual focal point of the system.