Infrared Scene Generator for a Flight Motion Simulator

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ABSTRACT

The paper describes an infrared scene generator (IRSG) mounted on a Flight Motion Simulator (FMS) for hardware in the loop simulation of IR air to air missile seekers. The scene generator projects target, flare and background images, that are optically collimated to the seeker under test.

The target and flare images are generated using high temperature (1200C) blackbody sources and controllable irises. A dynamic Variable Neutral Density Filter (VNDF) is used in the target and flare channels to simulate the range closure and attenuation effect of the atmosphere.

The background channel consists of a back illuminated IR transparency located in front of an extended area blackbody. The target flare and background images are combined using two beam combiners. One of the beam combiners has two degrees of freedom to simulate the motion of the flare relative to the target within the field of view (FOV) of the IRSG.

1. INTRODUCTION

Infrared seekers and payloads are becoming more and more sophisticated, carrying advanced target acquisition, recognition and tracking capabilities. Testing these expensive seekers is becoming not only more important, but also more difficult to accomplish. In fact, construction of scenarios in simulation must be more and more realistic in order to be useful.

Hardware-in-the-loop simulation by infrared scenarios is becoming a common testing method of missiles, because it is less expensive than field tests. [1,2]

CI Systems has built an IR Scene Generator (IRSG), that is mounted on a flight motion simulator (FMS). This system is capable of simulating an engagement scenario of a missile closing on a target and a dynamic flare, moving simultaneously with respect to a textured background.

The spatially textured radiation of the background is achieved by a special IR transparency called Thermoscene.[3] The Thermoscene is made of a matrix of up to 512 x 512 pixels and is placed on the optical path of the IR radiation generated by an extended area blackbody.

 0-8194-1269-4/93/$6.00

The relative radiance level of each pixel may be set on the Thermoscene to any of the available grey levels. The number of pixels per picture can be increased at the expense of the number of grey levels, by reducing the pixel's size.

The IRSG operates in the 2 to 5µm spectral range and is fully computer controlled.

2. SYSTEM DESCRIPTION

2.1 General description

The IRSG is an electro-optical system, shown in figure 1, which creates a semi-dynamic scene, in the 2-5µm spectral band, of a target on a static background at infinite range. The target is capable of dispensing a flare in an autonomous trajectory. In addition, the closing range between the missile and both the target and the flare is simulated by changing their subtended angle. The IRSG is controlled by a PC that serves as the local slave computer. An AD-100 computer serves as the host and governs the IRSG and the FMS during a hardware-in-the-loop simulation.

The IRSG is composed of three main units:

a) The Electro-Optical Bench Assembly (EOBA), contains all the optical and electromechanical elements used to generate the IR scene. The EOBA block design is depicted in figure 2.

b) The Control Electronics Rack Assembly (CERA), includes all controllers and electronics needed to drive the EOBA components.

c) The PC with its software generates the simulation scenarios, interfaces the CERA and the AD-100 host computer.

2.2 Electro Optical Bench Assembly

2.2.1 Target Scene Generator (TSG)

The TSG consists of a controllable 1200C, cavity blackbody. A specially designed shutter is located between the blackbody and the VNDF. The circular VNDF is also located on the optical path. Its motorized, computer controlled, rotation varies its transmission thus functioning as a variable attenuator. The transmittance of the VNDF may vary by a ratio of 1: 50. A condenser lens is positioned between the TSG iris and the VNDF and used to match the blackbody exit aperture with the TSG iris. The motorized iris is positioned at the focal plane of the TSG collimator. The TSG iris has a triangular opening. It opens from zero to a maximum size of 30 mrad, at a maximum velocity and acceleration of 0.3 rad/sec and 10 rad/sec^2 respectively. The final assembly in the TSG channel is the collimator which consists of 2 lenses potted in an aluminum housing.

The target image is stationary at the center of the FOV of the IRSG. The simulation of the relative motion with unit under test (UUT) is realized by the motion of the two outer axis of the FMS, on which the IRSG is mounted.

2.2.2 Flare Scene Generator (FSG)

The FSG channel is almost identical to the TSG except for its iris. The FSG iris has a circular opening that opens from zero to a maximum size of 15 mrad.

2.2.3 Flare Steering Assembly

The motion of the flare in the FOV is achieved by rotating the second beam combiner in two perpendicular directions. The flare trajectory starts at the center of the FOV, where it coincides with the target and can move across the whole IRSG's FOV. The flare maximum velocity and acceleration are 1 rad/sec and 4 rad/sec^2 respectively.

2.2.4 Background Scene Generator (BSG)

The BSG consists of a controllable extended area blackbody. A condenser lens is positioned between the blackbody and the Thermoscene. The Thermoscene is placed on the focal plane of the BSG collimator . The background image fills the whole FOV of the IRSG.

2.3 Control Electronics Rack Assembly

The IRSG CERA is a 19" console, 30V high stand-alone unit. The CERA interconnects with the IRSG through a 15 meter cable and to the IRSG IBM PC through a 4 meter cable. The IRSG consists of three blackbodies temperatures controllers (TSG, FSG, & BSG). These controllers are remotely controlled by the PC through an IEEE-488 Bus. It is also possible to set the blackbodies' temperature from the controllers front panel when in local mode. The CERA also includes the power amplifiers and drivers for the DC servo motors. The commands to the drivers are received from the PC where the motion controller is resident. Shutter controllers are activated by a TTL command issued by the PC. The default of the shutters is normally closed.

2.4 The PC and its software

An IBM PC compatible is used to operate and control the IRSG. A Delta-Tau PMAC controller is mounted on one of the PC's slots. The PMAC controller receives the real time reference data from the AD 100 host computer and closes the loop on the five motion controlled motors position using optical encoders as the feedback device.

The AD 100 host computer uses an ICON printed circuit board to communicate with the ICON compatible printed circuit board, residing in the PC through a DRV11 bus. An IEEE printed circuit board is mounted on the PC communicates with the TSG, FSG, and BSG blackbodies controllers, located on the CERA through an IEEE 488 bus. The software includes drivers for the communication with the host computer and blackbodies and the manual operating mode.

3. OPTICAL DESIGN

3.1 General Description

The role of the optical system layout shown in figure 3, is to collimate the image of each IRSG channel, combine all beams using beam combiners and then expand the combined wavefront using an afocal telescope. The individual images are generated at the focal plane of each channel's collimating optics, by means of irises in the TSG and FSG channels and the Thermoscene in the BSG channel. Blackbodies are used as the IR radiation sources.

The afocal telescope concept has two purposes:

a) The IRSG free volume constrains prevent the positioning of the BSG, TSG and FSG near the IRSG exit aperture. The afocal telescope serves as an optical relay, images the UUT's entrance pupil to an area closer to the azimuth gimbal where the BSG,TSG and FSG can be located.

b) The afocal telescope with its magnification of 2, is used to minimize the size of the apertures within the IRSG and thus reducing the size of the optical components.

Beam combiner #1 is located close to the entrance pupil of the telescope. The BSG channel is located on the transmitting path of beam combiner #1. The background is static. The path of the reflected beam from beam combiner #1 contains the combination of the collimated Target and Flare (TSG, FSG) scenes. The second beam combiner is located next to beam combiner #1 (on its reflected path). The target scene is project through beam combiner #2 along its transmitting path, while the FSG scene is reflected by the beam combiner. The second beam combiner is mounted on a two rotational degrees of freedom pedestal. Its angular movement results in the movement of the FSG image in the FOV, relative to the target.

3.2 Optical Relay

The afocal telescope, acting as a relay, is composed of five lenses. It places the IRSG exit pupil 390 mm from its front lens so at to locate the exit pupil at the FMS axes intersection where the UUT clear aperture is located. This feature provides the UUT with a full unvignetted beam over its whole entrance pupil.

The relay has an intermediate real image plane that is used as a field stop, thus eliminating stray light effects.

3.3 BSG Optics

The BSG overall optical system includes the BSG front optics, beam combiner #1 and the optical relay as shown in figure 4. The BSG front optics - relay combination forms a corrected collimator for the spectral range of 2-5μm.

3.4 FSG Optics

The FSG channel consists of an achromatic doublet - relay combination. It is corrected for the spectral range 2-5μm. Figure 5 shows its layout and ray tracing, with the second beam combiner at the extreme position. The FSG exit pupil is placed coincident with the BSG exit pupil. The FSG front optics is determined by the exit pupil, beam wander on the aperture of the doublet and vignetting at the extreme flare positions.

3.5 TSG Optics

The TSG optics is similar to the FSG optics. The optical layout is shown in figure 6.

4. CONCLUSION

The IRSG is modular and compact, and rugged, making it suitable for mounting on dynamic platforms such as Flight Motion Simulators. The IRSG modular design enables its easy upgrading to operate in the 8-12μ spectral band, and adding motion capabilities to the target (relative to the background).

5. ACKNOWLEDGEMENT

CI Systems expresses its appreciation to Sturlesi Computation Engineering for the performance of the IRSG optical design.

6. REFERENCES

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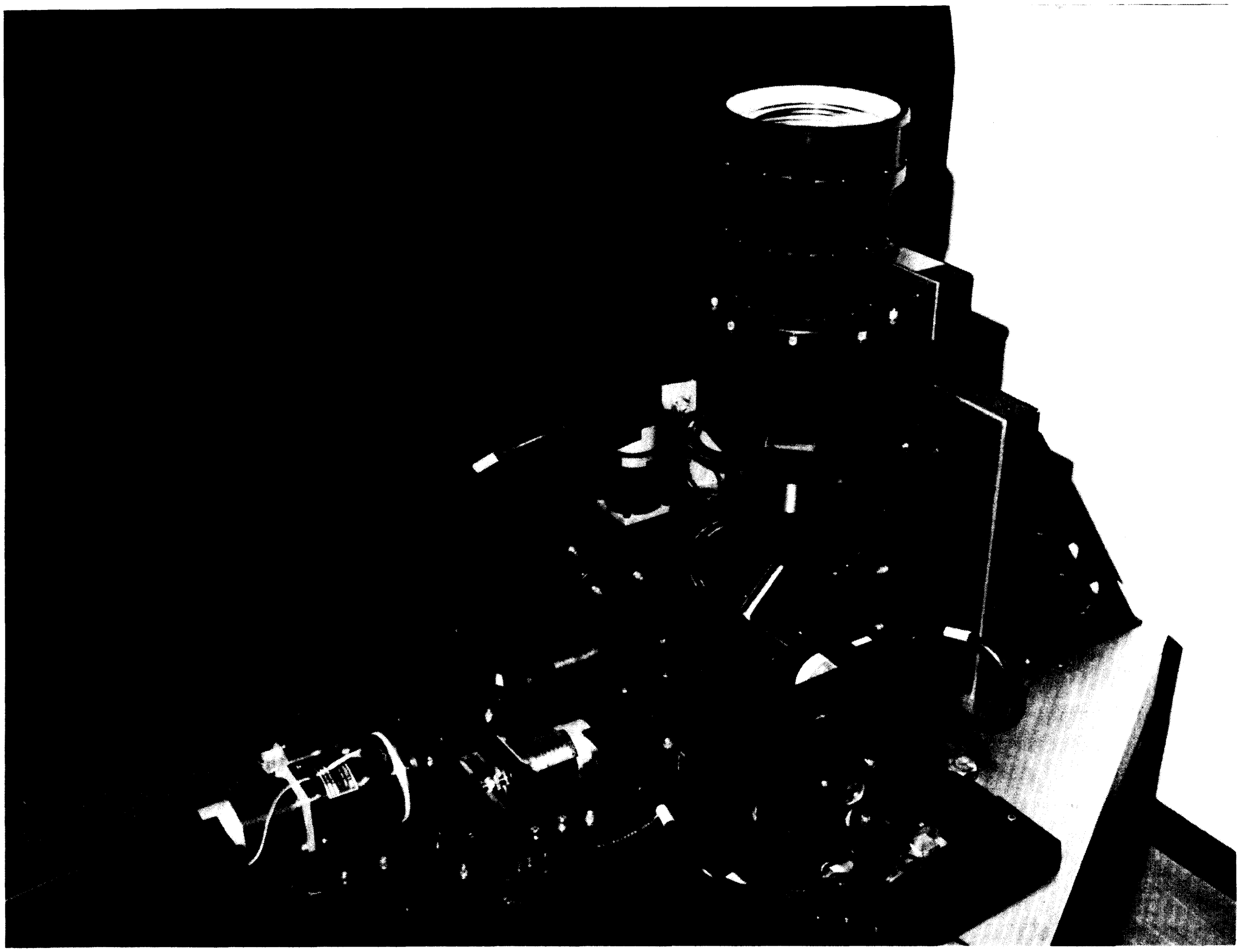

Figure 1: IRSG electro-optical bench assembly general view - cover removed

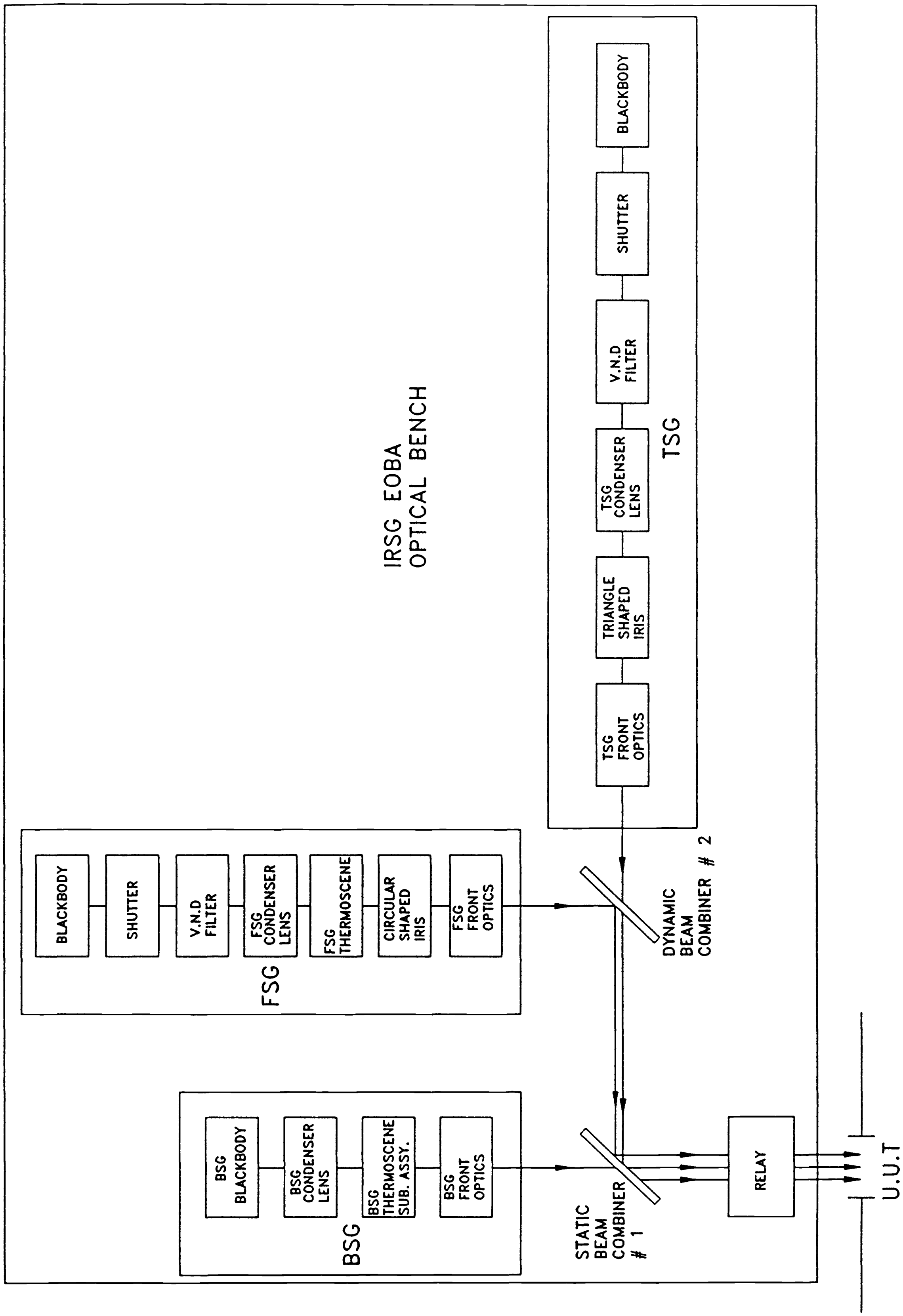

Figure 2: IRSG EOBA configuration

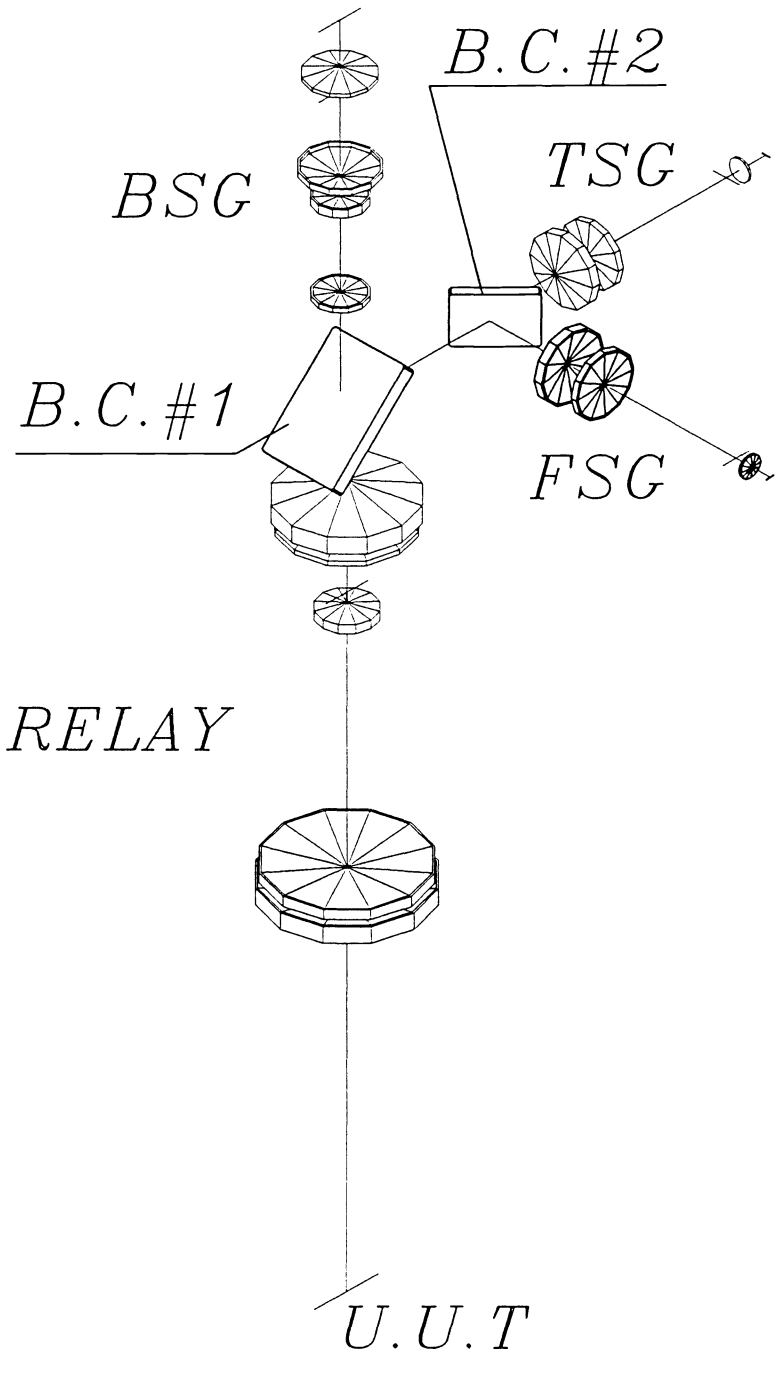

Figure 3: IRSG optical layout

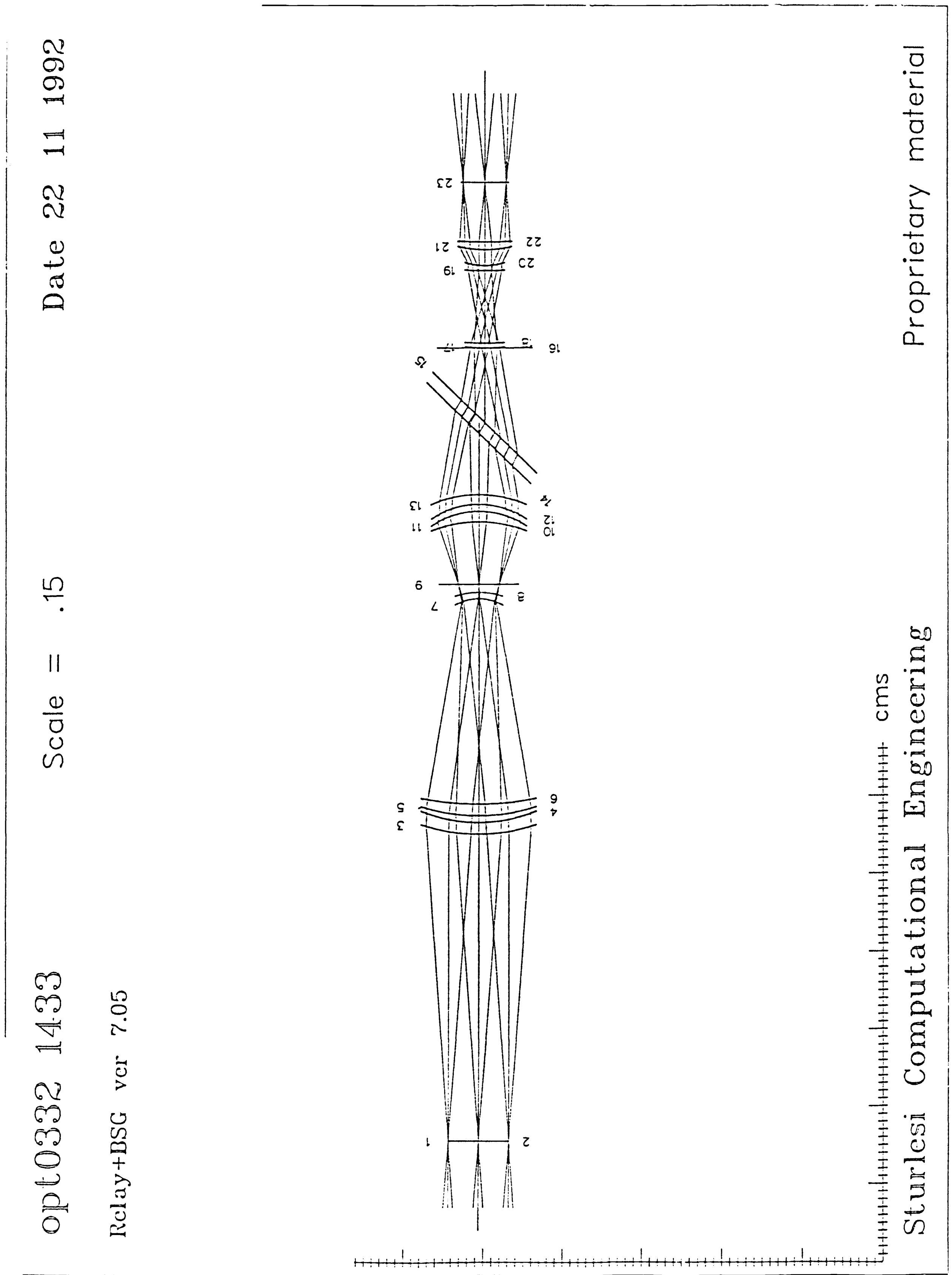

Figure 4: BSG optical layout and ray tracing

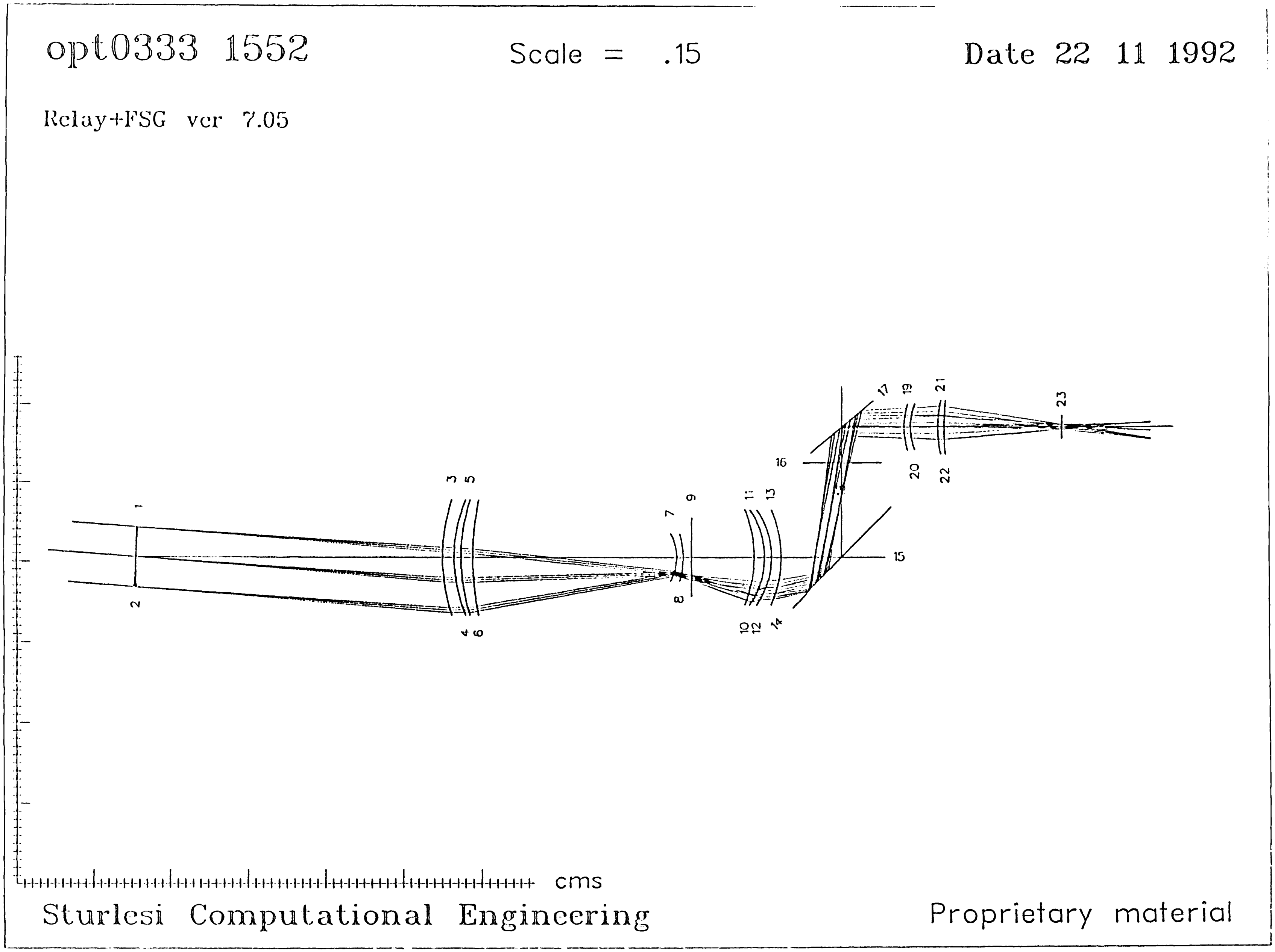

Figure 5: FSG optical layout and ray tracing

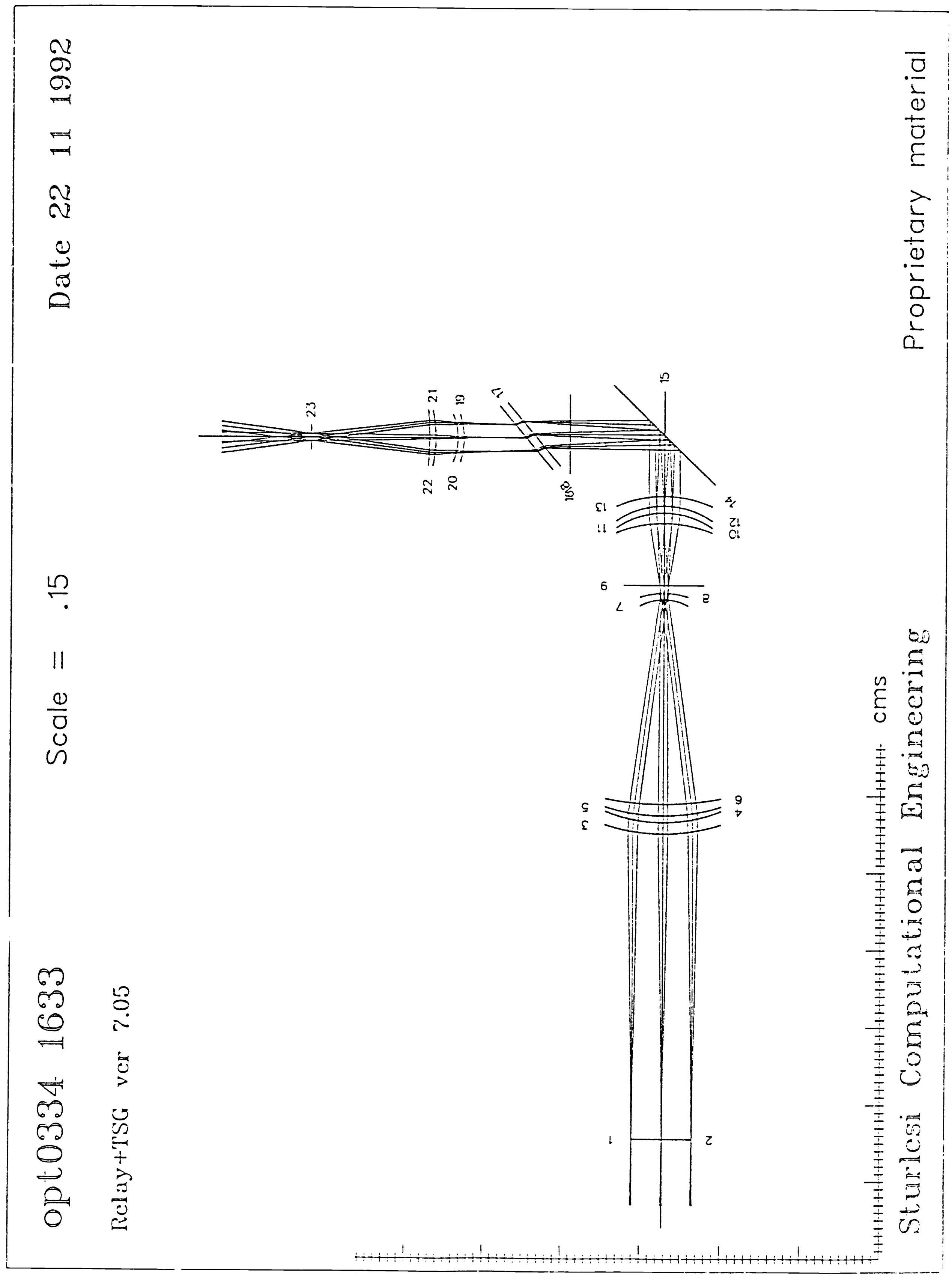

Figure 6: TSG optical layout and ray tracing