3 Toepler’s Schlieren Technique

They said ‘You have a blue guitar,
You do not play things as they are.’
The man replied, ‘Things as they are
Are changed upon a blue guitar.’

*Wallace Stevens*, *The Man with the Blue Guitar*

‘Schlieren apparatus’ is a name just as suitable or unsuitable as the name ‘telescope,’ for as the latter is a scope to see distance, so is the former an apparatus to see Schlieren.

*August Toepler* [135]

Why do we call it Toepler’s technique? Recalling Chap. 1, although Toepler was not the strict originator of schlieren imaging, he made it what it is today. Here, *Toepler’s schlieren technique* distinguishes the basic (lens or mirror) schlieren system with slit-source and knife-edge from all the other adaptations that have arisen since his time.

Toepler also stated some lasting design principles for schlieren equipment [12,37]. His apparatus (see Fig. 1.8) was arranged in three sections: the “illuminator,” the “schlieren head” or main field lens, and the “analyzer.” (Today dual field lenses or mirrors are more often used instead of a single schlieren head.)

A variety of schlieren arrangements is possible, all embodying Toepler’s design principles [66]. Our goals in this chapter are to discuss the basic setups, and to consider the salient properties of the resulting schlieren image in detail.

### 3.1 Lens- and Mirror-Type Systems

Although Toepler originally used the objective lenses of refracting telescopes as schlieren heads, mirror-based systems followed shortly on the strength of Foucault’s knife-edge test. There are some distinctions worth noting at the outset.

While lens-type schlieren instruments can be in-line, and therefore relatively simple, mirror-type instruments are inherently folded. This is not a problem for routine work unless one uses too many mirrors. But mirror-based instruments
tend to be rather more difficult to align, and troublesome off-axis optical aberrations can occur under circumstances to be explained later.

On the other hand, chromatic aberration matters for a lens, but not for a first-surface mirror. In fact, residual chromatic aberration is a problem even for expensive achromatic lenses, due to partial spectrum cutoff by the knife-edge. This causes color anomalies in the schlieren image, which sometimes appears split into halves of spectrally-opposite colors. A narrow-band color filter at the light source eliminates this difficulty (Toepler [3,37]).

Further, modern multi-element lenses require high internal quality and several optical surfaces polished to near-perfection, while mirrors need only one polished surface and little internal quality. These factors weigh in favor of mirrors when cost and field-of-view are considered. Accordingly the largest lens-type schlieren instruments to be found are in the 20 cm-diameter range. Larger systems – except for the special ones described in the next chapter – are always mirror-based.

Some typical commercial prices for schlieren-quality lenses and mirrors are plotted vs. diameter in Fig. 3.1. An exponential rise of cost with diameter is evident, depending upon manufacturer, with the steepest rise in the case of lenses. Lens cost also increases with higher lens power. Mirrors and lenses of larger diameter than those of Fig. 3.1 can be had by special order, but meager data prevent any general comments on cost outside the range shown (see App. D).

![Fig. 3.1. Cost in US$ vs. diameter for achromatic lenses ▲ and parabolic telescope mirrors □ suitable for use as schlieren field optics. (These data are for example purposes only, and are extracted from commercial catalogs ca. 2000.)](image)

### 3.1.1 Lens Systems

Sharp high-quality lenses are always favored for schlieren work. The schlieren objects themselves are often quite weak, so lens imperfections can easily mask them. Surface figure within at least $\lambda/2$ over the lens diameter is required for such high-sensitivity work. Correction of both spherical and chromatic aberration is important. Internal striae are annoying, but as Weinberg [66] says: “One or two well charted familiar (streaks) across the field of view...will not seriously interfere with research or teaching.” Telescope objectives, projector lenses, and military-surplus aerial camera lenses often make good schlieren field lenses.

Schardin [1,2] discussed Toepler’s [41] single-lens schlieren system in detail. Shown in Fig. 3.2, its light source is extended, but must have at least one edge