Visible targets

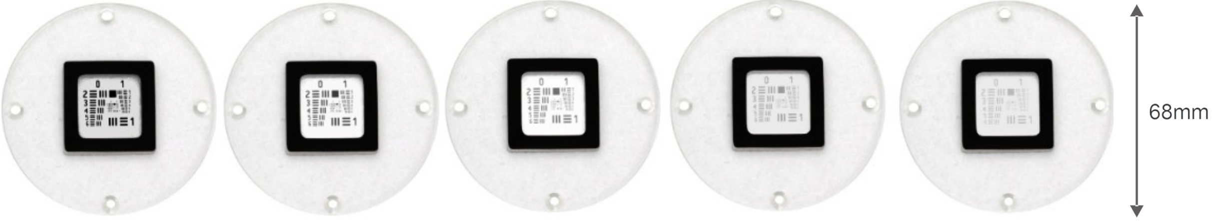


Fig. 1. Photo of a set of typical visible targets: variable contrast USAF1951 targets

1 Types of targets

Targets are modules that can create image of reference patterns needed when testing electro-optical imaging systems. The targets manufactured by Inframet can be divided into two groups:

1. Passive targets
2. Active targets.

The passive targets need to be irradiated by a uniform beam of light generated by blackbodies or calibrated light sources in order to create images of reference image patterns. These targets are typically small modules of bigger test systems. The passive targets do not need electric power for proper work.

The active targets create images of reference image patterns due to their own thermal radiation or due to reflected light emitted by sources typically met in human environment. These targets are typically big stand alone modules that need electric power for proper work.

The passive targets can be divided according to application on three groups:

1. Infrared targets (IR targets),
2. Visible targets (VIS targets),
3. Night vision targets (NV targets).

The IR targets are used for testing thermal imagers operating at MWIR-LWIR spectral band. VIS targets are used for testing color VIS cameras, monochromatic VIS-NIR cameras, or VIS-SWIR cameras operating in VIS-SWIR spectral band. NV targets are used for testing nigh vision devices operating in VIS-NIR spectral band.

These three group of targets differ due to manufacturing technology even if both VIS targets and NV targets work in similar spectral band. In addition, the NV targets are several times bigger comparing to IR/VIS targets. The latter targets are to be inserted into holes of a rotary wheel (or target sliders), are relatively small (typically from about 50mm to about 100mm) and their exchange is typically motorized. NV targets are directly attached to a large night vision light sources (diameter up to about 210mm) used in Inframet systems for testing NVDs and are manually exchanged.

2 How VIS targets are made?

Visible targets are typically manufactured by creating non-transparent or partially transparent coating of required shape on highly transparent glass plate (case of positive contrast targets) or inverse situation (negative contrast targets). The coating is typically created using photolithography/photography methods by creating chrome/emulsion patterns on clear glass/foil substrate. These methods enable development of patterns of visible targets with sub-micrometer accuracy.

3 How VIS targets work?

The VIS targets are typically inserted to holes in motorized rotary wheels used in a series of Inframet test systems for testing VIS-NIR cameras, SWIR imagers or multi-sensor imaging systems based on a reflective collimator. The rotary wheel with targets is located at focal plane of a collimator and simulate infinity distance targets. A light source (LS-DAL or LS-SAL) is put behind such a target and the tested camera sees a "target" of shape determined by the reference pattern of the target. Typical VIS targets are manufactured on small 68mm plates to be fixed to MRW-8 rotary wheel (TVT, ST, MS test systems). The VIS targets can be also fixed to small manual target sliders and attached to a light source located on CDT collimator. This is the case of VINIS, SINIS and MIM test systems.

4 Contrast of optical targets

Optical targets are used to create images of reference patterns located on an uniform background when the target plate is illuminated by an uniform light source. Therefore technically definition of contrast of targets under surveillance by human eye or by electro-optical systems could be used to characterize contrast of optical targets. The problem is that there is a series of definition of contrast in literature and definitions of contrast of some targets offered on the market are unclear.

Inframet typically uses Weber definition of contrast

$$Contrast=\frac{L_T-L_B}{L_B} \tag{1}$$

where L_T is luminance of the target, L_B is luminance of the background. In case of optical targets luminance can be treated as transmission (or reflectance) and the formula (1) is converted to new form

$$Contrast=\frac{\tau_T-\tau_B}{\tau_B}=\tau_{Rel}-1 \tag{2}$$

where τ_{Rel} is relative transmission of the target (ratio of transmission of the target to transmission of the background.

Inframet has accepted Weber definition of contrast of optical targets because this definition is used by two old NATO standards [2-3] that regulate testing night vision devices (image intensifier systems). The standard Stanag 4348 presents formula that is practically identical as formula (2) but transmission is replaced by reflectance (assumption that reflective targets are used).

Both the standards [2-3] recommends testing night vision devices using optical targets that generate image of dark reference target located on uniform bright background. In fact, testing of all types of VIS-SWIR imaging systems (visual optical systems, VIS-NIR cameras, VIS cameras, SWIR imagers) is typically done using such targets.

The formula (2) indicates the contrast of target plates recommended by the standards [2-3] and typically used in testing VIS-SWIR imagers is below zero and logically such targets should be called negative contrast targets because they generate negative contrast image [4]. However, manufacturers of optical targets for unknown reasons call targets that generate image in form of dark pattern on a bright uniform background as positive contrast targets and targets that generate image in form of bright pattern on a dark uniform background as negative contrast targets [5-6]. In order to correlate with this market reality Inframet uses the same positive contrast/negative contrast definition although it is against logic of formula (2) and some literature [4].

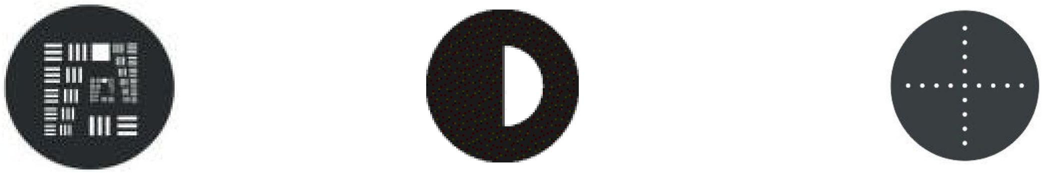
Literature

1. https://en.wikipedia.org/wiki/Contrast_(vision)
2. STANAG 4348, Definition of nominal static performance for image intensifier systems.
3. STANAG 4351, Measurement of the minimum resolvable contrast (MRC) of image intensifier systems.
4. Werner Adrian, Visibility of targets, Transportation Research Record 1241, 1989
5. https://www.edmundoptics.com/p/2-x-2-negative-1951-usaf-resolution-target/4305/
6. https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=4338

5 Patterns of VIS targets

INFRAMET manufactures VIS targets that can generate images of three main patterns: USAF1951, semi-moon, dot cross (Table 1).

Table 1. Patterns of VIS targets typically manufactured by Inframet



a)USAF 1951 b)Edge c)Dot cross

Applications of targets in Table 1 are presented below.

5.1 USAF1951 targets

Visible targets are mostly used as resolution targets. There have been proposed many different types of resolution targets. However, Inframet prefers positive contrast (opaque pattern on transmissible substrate) USAF 1951 target because of its universality (ability to measure resolution of both low resolution and high resolution imagers).

The USAF 1951 targets of 100% contrast are available commercially from many different sources because 100% contrast targets are relatively easy to be manufactured. However, the typical targets of 100% contrast poorly simulate real low contrast targets met at field conditions and are almost useless to measure real performance of VIS-NIR, and SWIR cameras.

Therefore Inframet offers USAF1951 targets in two forms:

1. positive 100% contrast USAF 1951 target for simple tests like resolution measurement,
2. set of five positive variable contrast USAF 1951 targets for expanded tests like Minimum Resolvable Contrast measurement.

Inframet has mastered technology of variable contrast resolution targets and Inframet offers USAF 1951 targets of contrast from about 4% to 100%. This span of contrast enables accurate testing and evaluation of performance of VIS-NIR cameras and SWIR cameras against real low contrast targets. It should be emphasized that ability of testing VIS-NIR cameras against low contrast target is of critical importance because such targets dominate in real applications. In addition, two VIS-NIR cameras often have similar resolution but differ much when low contrast targets are used. Therefore Inframet highly recommend making MRC tests for evaluation of VIS-NIR camera and also for any camera sensitive in VIS-SWIR range. Parameters of typical set of variable contrast USAF1951 targets for

MRC test are shown in Table 2.

It should be noted that contrast of VIS targets depends slightly on wavelength. Therefore Inframet delivers the variable contrast USAF 1951 targets having contrast measured for three popular types of VIS-SWIR imagers: color visible cameras, monochromatic VIS-NIR cameras, nocontrast of targets is measured at three bands: VIS cameras (color cameras)sensitive in 450-750nm band, VIS-NIR cameras (monochromatic CMOS cameras) sensitive in 400-1000nm band, SWIR cameras (non cooled InGaAs cameras) sensitive in 950-1700nm band.

Table 2. Parameters of typical set of variable contrast USAF1951 targets for MRC test

Technology	Parameter
number of targets for MRC tests	6
Contrast of set of targets	distributed in range from about 4% to 100%
Spatial frequency range	1-456 lp/mm for 100% contrast target at least from 1 lp/mm to 128 lp/mm for lower contrast targets
Spectral bands dependence	contrast of targets is measured at three bands: VIS (color cameras), VIS-NIR (monochromatic cameras), SWIR (non cooled InGaAs cameras)
Dimensions of internal plate where resolution pattern in located	about 25x25mm
Diameter of total target plate	typically about 68mm (depends on type of rotary wheel to be used

6 Edge targets

Edge targets are typically manufactured to have a single hole in metal sheet in form of a semi-moon or semi-square. The latter shape has advantage of larger area on both sided of the edge that can be analysed.

These targets are used in measurements of modulation transfer function MTF of thermal imagers to simulate step change of temperature. Inframet offers edge targets having local deviation from straight line at level below 2 µm. It is a sharp contrast to typical edge targets cut from thin metal sheets using laser technology when the deviation can be as high as 10 µm and this non perfect shape of the edge can influence measurement results.

The edge targets are typically delivered as so called slanted edge target. It means that the edge line is slightly rotated by an angle about 5° relative to vertical/horizontal planes. This slanting is needed to enable subpixel sampling of edge image during MTF calculation.

7 Dot cross targets

Dot cross targets are used to create, after they are fixed at collimator focal plane, images of known angular size. Imager of these targets generated by tested imagers are analysed by software and FOV and distortion are measured.

8 Angular parameters of VIS targets

VIS targets are typically used as blocks of image projectors. They are located at collimator focal plane and combined with an light source located just behind the target generate image of a reference target of required shape in VIS-SWIR spectral band. The angular properties of projected image depend not only on linear dimensions of the pattern in the VIS target but also on collimator focal length. Therefore the same VIS target can generate a series of reference images of of different angular properties.

Three angular parameters are used to characterize angular properties of projected image: spatial frequency, angular size and more rarely inverse angular size.

Spatial frequency is a parameter used to characterize periodic targets like 3-bar targets (USAF1951 targets). The spatial frequency is a measure of how often periodic function (sinusoidal or rectangular) repeat per unit of angle.

The spatial frequency *SF1* (in line pair per mrad unit) of image of USAF1951 target located at collimator focal plane of typical image projector can be calculated as

$$\mathrm{SF1[lp/mrad]} = \text{focal length [mm]} \quad \mathrm{SF2[lp/mm]}. \tag{3}$$

Target angular size α in mrad unit is calculated as

$$\alpha=\frac{a}{f'} \tag{4}$$

where a is target linear size in mm unit and *f'* is focal length of the collimator in meter unit.