CDT

Off axis reflective collimators

Fig. 1. Photo of several CDT series collimators

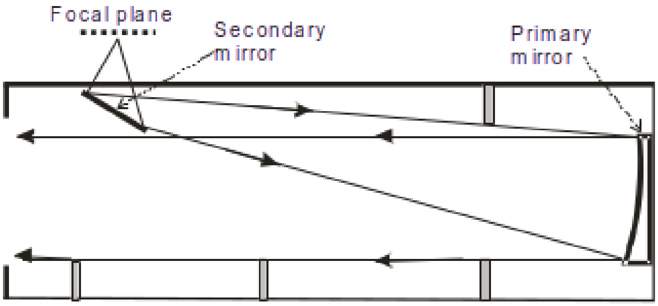

Fig. 2. Block diagram of off-axis reflective collimator (CDT series)

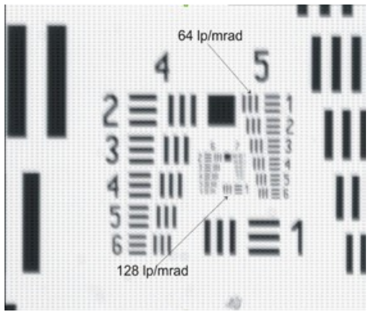

Fig. 3. Photo of an USAF 1951 target projected by a CDT collimator

BASIC INFORMATION:

Collimators are optical systems used to imitate standard targets placed in "optical infinity" (very long distance). The collimators are used for projection of image of reference targets into direction of tested imagers. According to type of optical elements used in design, collimators are divided into two groups: reflective collimators and refractive collimators. Reflective collimators due to their wide spectral range are almost exclusively used in systems for testing thermal imagers and are also preferable in systems testing TV cameras, SWIR imagers, laser systems or multi-sensor surveillance systems. Refractive collimators are mostly used in systems for testing night vision devices or TV cameras working in visible/near infrared range.

From optical designer view, the reflective collimators are inverted telescopes. Therefore it can be claimed that there are many types of reflective collimators depending on mirrors configurations (Newton, Cassegrain, Schwarzschild, Maksutov, etc). However, practically reflective collimators are typically built using Newton design (big parabolic primary, collimating mirror and smaller secondary flat mirror).

Next, the reflective collimators can be divided into two basic types: on-axis collimators and off axis collimators. The first collimators have a dead area in center of their optical aperture due to presence of a non transmitting, secondary mirror. This feature limits significantly applications of on axis collimators in systems for testing imagers. There is a risk that the dead area of the on-axis collimator can distort measurement results when only a part of aperture of optics of tested imager is used to create image.

Off axis collimators offers un-obstructed aperture because the secondary mirror is located outside collimator aperture (Fig.2). However, off axis reflective collimators are also much more costly than reflective on axis collimators. Low cost symmetric parabolic mirrors are used to design on-axis reflective collimators. Non symmetric mirrors (parts of a bigger mother symmetric mirror) are needed in case of off axis collimators. Next, aligning of off-axis collimators is more difficult than in case of typical on axis collimators.

Inframet manufactures a long series of CDT off axis reflective collimators that are used as blocks of Inframet test systems or sold as independent optical modules.

CDT

Off axis reflective collimators

1. HOW OFF AXIS COLLIMATORS ARE BUILT:

Off axis collimators are built using two mirror configuration: primary off axis collimating mirror and secondary flat mirror. These collimators offer un-obstructed aperture of the primary collimating mirror because the secondary mirror is located outside collimator output aperture (Fig.2). The primary mirror is manufactured as a non-central part of a bigger parabolic mirror (mother mirror). The secondary mirror is manufactured as a flat mirror in form of an ellipse.

2. MARKET SITUATION:

In spite of this simple optical structure manufacturing high quality off axis reflective collimators is a technical challenge, particularly in case of collimators of big optical apertures. Manufacturing off axis parabolic mirrors with high accuracy (deviations from theoretical parabolic surface must be fractions of wavelength of light) is a technological challenge. Aligning of off axis collimators is difficult, too. Therefore, there are very few companies all over the world that mustered technology of manufacturing off axis reflective collimators. Next, there are several myths on these optical systems that create confusion among their users. Therefore this data sheet presents detail information that enables evaluation and optimal choice of off axis reflective collimators needed for a wide range of applications.

3. MIRRORS MATERIAL

Mirrors for off axis collimators are manufactured from two main types of materials: glass and metal.
Metal off axis parabolic mirrors are available on mass market at relatively low cost but are poorly suited for use in image projectors, particularly in visible/near infrared range. Manufacturing accuracy of best metal mirrors is several times lower than accuracy of average glass mirrors. Therefore metal mirrors will not be discussed here.

There are four main types of glass that are most often used in mirrors fabrication: optical crown glass, low-expansion borosilicate glass (LEBG), synthetic fused silica and Zerodur.

The material for mirror fabrication should be chosen on the basis of four parameters: coefficient of thermal expansion, cosmetic surface accuracy, surface accuracy, and material cost.

Optical crown glass (often BK7 type) is an old matured material for mirrors. Crown glass has a relatively high coefficient of thermal expansion and is employed when thermal stability is not a critical factor.

Low-expansion borosilicate glass (LEBG) known by the Corning brand name - Pyrex - is well suited for high quality front-surface mirrors designed for low optical deformation under thermal shock. Pyrex coefficient of thermal expansion is lower than in case of optical crown glass but quality defects are more common. .

Synthetic fused silica has a very low coefficient of thermal expansion. Fused silica mirrors can be polished to extreme accuracies, thereby minimizing wavefront distortion and scattering.

Zerodur is a unique glass-ceramic material whose thermal expansion is almost zero. This stability is essential in diffraction limited systems where the optical figure must not vary under thermal changes.

Inframet typically use mirrors manufactured from borosilicate glass. Mirrors from synthetic fused silica or from Zerodur are used only for collimators to be used at extreme temperature conditions.

4. MIRRORS MANUFACTURING ACCURACY

Mirror manufacturing accuracy is a crucial parameter that determines quality of images projected by reflective collimators. Applications of off axis collimators differ significantly and the same can be said about requirements on quality of these collimators. Requirements on mirrors to be used in collimator for testing short/medium range thermal imagers (wide/medium FOV) are several times lower than in case of collimators used in testing long range thermal imagers (narrow FOV). Requirements on collimators used for testing long range TV cameras in space applications are even higher. Therefore Inframet use three basic classes of off axis mirrors:

- SR (standard resolution) - manufacturing accuracy P-V not worse than about $\lambda/2$ at $\lambda = 630$ nm,
- HR (high resolution) - manufacturing accuracy P-V not worse than about $\lambda/6$ at $\lambda = 630$ nm,
- UR (ultra high resolution) - manufacturing accuracy P-V not worse than $\lambda/10$ at $\lambda = 630$ nm,
- SQ (space quality) - manufacturing accuracy P-V not worse than $\lambda/14$ at $\lambda = 630$ nm.

SR mirrors are cheapest used on collimator of low/medium requirements. SQ class mirrors are most expensive mirrors that are only rarely used in collimators to be used for testing space imagers of ultra narrow FOV.
Mirrors of higher manufacturing accuracy can potentially generate high quality images only if used in properly aligned collimators. Therefore SR/HR/UR/SQ symbols determine not only mirror manufacturing accuracy but also class of aligning of the collimator.
Details rules how to choose between SR, HR, UR or SQ collimators are presented later.

5. COATINGS

Spectral range of the reflective collimators is determined by coatings of the mirrors. Metallic coatings are typically used as reflective coatings in IR mirrors. There are three types of most often used metallic coatings: aluminum, silver and gold. All three types of coatings offer similar high reflectivity over about 95% in the spectral range of interest: 1-15 μm but differ in performance in visible&near infrared range 0.4-1 μm. Next, all mentioned above coatings need some kind of dielectric overcoat that arrests the oxidation process or to improve its mechanical properties.

Gold offers consistently very high reflectance (about 99%) from about 0.8 μm to about 50 μm. Silver offers slightly lower reflectance (about 97%) but broader spectrum from 0.3 μm to over 20 μm. Aluminum coatings are characterized by lower average reflectivity (about 96%) at wavelength over 2 μm and a certain reflectivity drop in visible and more in near infrared. From the other point of view the aluminum coatings are characterized by the very good durability and the lowest costs. Additionally, reflectance of aluminum coatings increases with a wavelength. Practically, there is only a slight difference in 3-15 μm spectral region between aluminum mirrors or gold mirrors in case of collimating mirrors, where a mirror surface is nearly perpendicular to the incoming beam. This difference increases in case of secondary flat mirror working at about 45 deg angle.

Inframet uses typically protected aluminum as coating for both mirrors. If uniform reflectance in both visible and near infrared is then protected silver coating is used for the secondary flat mirror or both mirrors. If ultra high reflectance in far infrared is needed then the secondary mirror (both mirrors) are coated using protected gold.
Transmittance values of collimators having mirrors with different combinations of coatings are shown in table below.

Table 1. Transmittance of reflective collimators built using mirrors coated using different materials

No	Coating	Transmittance				
		VIS	NIR	SWIR	MWIR	LWIR
1	Both mirrors - protected aluminum	0.77	0.77	0.86	0.92	0.93
2	Primary mirror - Protected aluminum; Secondary mirror – protected silver	0.84	0.84	0.9	0.93	0.93
3	Both mirrors - protected silver	0.93	0.93	0.93	0.93	0.93
4	Primary mirror - Protected aluminum; Secondary mirror – protected gold	0.53	0.86	0.92	0.95	0.95
5	Both mirrors - protected gold	0.36	0.96	0.96	0.96	0.96

Attention: Collimator transmittance vary with wavelength. Values in this table are only estimation.

As we see in Table 1 transmittance of reflective collimators can be increased by using silver coating or gold coatings. However, it should be remembered that silver coating is more vulnerable to humid climate or industrial pollution than typical aluminum coating. Next, gold offers excellent durability but at cost of drastically lower transmittance at visible spectral band.
Further on, transmittance can be even more increased if coating is not protected (no dielectric overcoat). However aluminum coatings and silver coatings quickly deteriorate without dielectric overcoat. Gold coating is very durable even without dielectric overcoat but is also very soft and vulnerable to dust. Therefore mirrors in Inframet collimators have always metallic coating with protected dielectric overcoat.

6. COLLIMATOR CONFIGURATION

Inframet typically manufactures off axis reflective collimators for work in so called vertical configuration.
Collimator focal plane is over collimator mirrors in vertical configuration (Fig.1). If the collimator is used in systems for testing thermal imagers then the rotary wheel is put on the collimator (in collimator focal plane). Next, the blackbody is located over the rotary wheel with targets.
This type of collimators enables design of compact test systems (only small narrow table is needed). There is also a more important advantage of collimators in vertical configuration. System for testing thermal imagers built using vertical configuration collimators offer better blackbody temperature uniformity than systems built from the same modules but in horizontal configuration.

This difference in performance is caused by smaller air fluctuation in vertical configuration test systems (more details *in K. Chrzanowski, Li Xian-min, Configuration of systems for testing thermal imagers, Optica Applicata, Vol. 40, 4, 2010*).

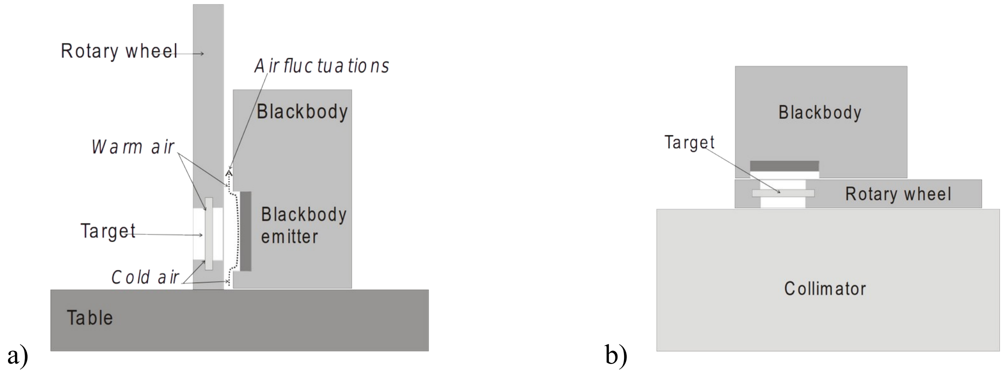

Fig. 4. The blackbody, the rotary wheel and the targets of the test system a)horizontal configuration, b)vertical configuration

Vertical configuration collimators are recommended due to compactness of test systems built using such collimators for any applications. However, it should be noted that Inframet can also deliver collimators in horizontal configuration having focus at the same height as optical axis. This configuration is enables design of more flexible test systems where all block are located on an optical table.
Changing collimator configuration is technically a simple rotation by 90º of the main cylindrical block. However, Inframet should be informed what configuration is preferred when order is sent.

7. COLLIMATOR PARAMETERS

There are five important parameters of off axis collimators: aperture, image quality criterion, focal length, FOV (field of view), transmittance.
Aperture is the diameter of the maximal ray beam that can be generated by the collimator when a point source is used. In detail aperture is a diameter of the collimating mirror of the collimator. Theoretically collimator aperture determines maximal aperture of tested imager. Practically, it is recommended that collimator should be at least 10% bigger than aperture of optics of tested imager to allow easy aligning the system imager-collimator.

There are different ways are used to characterize **image quality** of collimators and there is a confusion in this area.
Mirrors manufacturing accuracy or collimator wavefront accuracy are indicators of possible collimator quality. However these parameters do not give warranty about quality of collimator at user hands. The first parameter does not take into account possible aligning errors. The second one (rarely used) give information only about collimator ability to project image of a point located on the optical axis.

Resolution that is one of possible measures to characterize quality of image projected by this collimator. Resolution is defined as spatial frequency of minimal 3-bar target that can be resolved when image of such a target is projected using tested collimator. The test is done at visible band using astronomical telescope of ultra high quality. Suitability of the collimator for testing an imager can be determined by comparison of collimator resolution and resolution of the imager to be tested (Nyquist frequency). It is typically required that collimator resolution should be at least 5 times better than resolution of tested imager.
Details can be found at found at:

1. *Chrzanowski K., Testing thermal imagers – Practical guide, Military University of Technology, Warsaw, 2010 (Chapter 5).*
2. *Chrzanowski K, Evaluation of infrared collimators for testing thermal imaging systems, Optoelectronics Review, Vol. 15, No 2, 82-87, 2007.*

Focal length determines size of collimator. Shorter focal length means smaller more compact collimator. However, there are also some disadvantages of collimator of short focal length.
F-number is a ratio of collimator focal length to collimator aperture. F-number of off axis collimators offered on market vary from about 5 to about 12. Short focal length means low F number.
Low F-number collimators are characterized by small size that enables to decrease dimensions of the complete test system. However, thermal stability of low F-number collimators is lower than in case of high F-number collimators. Next, the most important disadvantage of low F-number collimators are significant geometrical aberrations that occur for off-axis targets. This means that low F number collimators project a perfect image of a spot located in the center of collimator field of view but image of any target located outside the center becomes

blurred. Details can be found at found at: *Chrzanowski K., Testing thermal imagers – Practical guide, Military University of Technology, Warsaw, 2010 p.89.* Due to this reason Inframet prefers collimators of higher F-numbers (F=10 for SR line and F= about 8 for HR line).

At the same time focal length determines range of spatial frequencies of resolution targets in angular spatial frequencies (line pair/mrad) projected by the collimator. The same resolution targets (typically 4-bar targets or 3-bar USAF 1951 targets) in linear units (millimeters) projected by different collimators represent different spatial frequencies in angular spatial frequencies (line pair/mrad). Therefore, required dimensions of targets depends on focal length of the collimator. Formulas to calculate angular spatial frequencies/dimensions of images of targets projected by different collimators are shown website section on infrared targets.
http://www.inframet.pl/infrared_targets.htm

Field of view (FOV) is angular size of maximal size of circular target that can be projected by the collimator. In simplification FOV can be calculated as a ratio of diameter of the secondary, flat mirror to focal length of the primary collimating mirror. Practically, collimator FOV give information how big can be targets located at its focal length.

In case of reflective off-axis collimators this angle is usually not bigger than about 2.5º. Field of view of thermal imagers is usually many times bigger than field of view of the collimator. However, collimator enclosure is also a source of thermal radiation and the thermal imager sees not only target plate and blackbody through holes in the target plate but also interior of the collimator. Because difference between temperature of the target plate and temperature of collimator case is usually very small then the imager see blackbody through target plate (pattern) on quasi uniform background. The conclusion is that these narrow FOV collimators can be used for testing imagers of much bigger FOV. The situations when imager FOV>> collimator FOV is typical. The only limitation is that big collimators of long focal length should not be used for testing short range commercial imagers because such imagers they generate poor quality image even of the biggest targets.

Situation is different in case of testing TV cameras, night vision devices or SWIR imagers. In the latter case the collimator generates small bright area on bigger dark background. When imager FOV>> collimator FOV then automatic gain control mechanism can work wrongly. Therefore manual control of AGC is typically required during testing TV cameras, night vision devices or SWIR imagers using systems based on reflective collimators.

Transmittance is ratio optical power emitted by target located at collimator focal plane and received by tested imager to optical power emitted by imager that sees directly a target of the same emittance and the same angular size. Collimator transmittance is calculated as a ration of reflectance of the primary collimating mirror and reflectance of the secondary flat mirror. Collimator transmittance (also collimator spectral band) depends on coating of the mirrors.

It is preferable to have mirrors of high transmittance of the collimator in full spectral range of interest. However, actually reduced transmittance of the collimator is acceptable as long the transmittance is known. In the latter case influence of limited transmittance of the collimator on measurement results obtained using such a collimator can be corrected. Values of transmittance of Inframet collimators are shown in Table 1.

Flange focal length of the collimator is a distance from collimator metal plate to focus plane. Flange focal plane typically optimized when the collimator cooperates with Inframet MRW-8 rotary wheel. This parameter is typically equal to 20.5±0.25mm (option: 20.5±0.05mm). However, we can deliver optional collimators having different values in range from 15 mm to 35mm.

8. HOW TO CHOOSE

Algorithm to choose optimal off axis reflective collimator is rather simple.

1. Determine aperture of required collimator as a diameter about 10% bigger than optics of biggest imager that can be tested. If multi-sensor is to be tested then ideal situation is when collimator aperture overlap optics of all sensors. However, it is acceptable when collimator aperture partially overlap optics of all sensors. The latter case enables to carry out accurate boresight of all sensors. Next, system can change is position relative to collimators during testing sensors.
   Be careful not to choose too big aperture. Bigger aperture means more expensive collimator. At the same time bigger aperture means longer focal length that can cause problems when testing imagers of wide FOV (short focal length).
2. Check if focal length of collimator of suitable aperture is acceptable. Look if targets of needed spatial frequency (or angular size) are offered for this collimator: http://www.inframet.pl/infrared_targets.htm It should be noted that Inframet typically offers collimators of focal length listed in Table 2. However, Inframet can manufacture custom designed collimators of any focal length.

3. Determine requirements on quality of images projected by the collimator or in other words requirements on collimator resolution. Check what is maximal resolution (Nyquestt frequency) of imager to be tested. Collimator resolution should be at least 5 times higher (10 times for perfect situation).

- SR collimators are recommended in non imaging applications or imaging applications when they project images of resolution targets of spatial frequency not higher than about 5 lp/mrad (ideal case) or not higher than 8-10 lp/mrad (optionally acceptable case).
- HR collimators are recommended in applications when they project images of resolution targets of spatial frequency not higher than about 25 lp/mrad (ideal case) or not higher than 30 lp/mrad (acceptable case).
- UR collimators are recommended in applications when they project images of resolution targets of spatial frequency not higher than about 60 lp/mrad (ideal case) or not higher than 100 lp/mrad (acceptable case).
- If requirements are higher then special, optional SQ class collimators are recommended. Please keep in mind that SR collimators are about 25% cheaper than HR collimators. Next, UR collimators are more expensive by about 30% comparing to HR collimators.

4. Determine requirements on coating on collimator mirrors. Recommended rules are:
   Testing thermal imagers: A)typical acceptable situation: protected aluminum on both two mirrors; B)optional perfect situation: protected aluminum on collimating mirror and protected gold on the flat secondary mirror. Case B eliminates slight drops of reflectance of protected aluminum at wavelength about 10 µm more noticeable in mirrors working at 45º angle.
   Testing SWIR imagers: The same rules as for thermal imagers.
   Testing TV cameras (visible/near infrared cameras): A)typical situation: protected aluminum on both two mirrors (acceptable but there is some non uniform transmittance in range from 400nm to 1000nm – negligible in most application); B)optional perfect situation: protected silver on both mirrors; or at least on the secondary mirror (high uniform transmittance in range from 400nm to 1000nm);
   Testing multi-sensor systems: A)typical situation: protected aluminum on both two mirrors; B)optional situation: protected aluminum on collimating mirror and protected gold on the flat secondary mirror (higher resistibility to strong laser pulses but low transmittance below 600nm), B)optional situation: protected silver on both mirrors or at least on secondary flat mirror (uniform transmittance in wide range from at least 400nm to at least 15000 nm but coating is more vulnerable to humid industrial environment conditions).
   Please keep in mind that optional coatings means additional small payment. In 98% customers prefer protected aluminum due lower cost and high durability.
5. Determine material for mirrors used in collimators. Low-expansion borosilicate glass used to manufacture mirrors used in typical Inframet collimators is a perfect material unless the collimator is to be subjected to quick temperature changes and very low temperatures (space applications or tests at temperature chambers). For the latter case Inframet can offer mirrors manufactured from Zerodur but such collimators are significantly more expensive.
6. Determine collimator configuration. Inframet can deliver collimators optimized to work in both vertical configuration or in horizontal configuration. However, Inframet must be informed about preferences. Both configurations are discussed in Section 6.
7. Determine flange focal length of the collimator. This parameter is typically equal to 20.5±0.25mm (option: 20.5±0.05mm). However, we can deliver optional collimators having different values in range from 15 mm to 35mm.

9. INFRAMET QUALITY CONTROL

Inframet carries out several stages of quality control of CDT off axis reflective collimators

1. Interferometric methods to evaluate quality of manufactured mirrors of MR, HR and SQ class. Foucault knife test is done in case of SR class mirrors. Certificates of mirror tests are delivered in case of HR/UR/SQ mirrors.
2. Inframet carries out final quality test of manufactured collimators by doing measurement of collimator resolution when collimator is working as image projector of USAF 1951 target in visible range. The measurement is done using ultra high quality telescope system based on CJT on axis collimator (mirrors manufacturing accuracy at least λ/16 at 630nm). Due to limited performance of the test tool (the telescope) the measurement results are always slightly worse than true resolution of tested collimator. However such a situation is safe for final users of the CDT collimators who can be sure that true resolution of

CDT collimator is better than the result presented in data sheet. This test method is in detail presented in the paper Chrzanowski K, Evaluation of infrared collimators for testing thermal imaging systems, Opto-electronics Review, Vol. 15, No 2, 82-87, 2007.

3. Final test stage is to verify if human observer can resolve bars of the smallest 4-bar target (or minimal 3-bar pattern in USAF 1951 target that is expected to be used) that was ordered when image of the target is projected by tested collimator. Image quality is analyzed using a commercial telescope. This test target is manufactured in a special low contrast (10%) version. If the test target can be easily resolved by human observer then it means influence of CDT collimator on accuracy of measurement results generated by DT systems is at acceptable level.

Attention: Inframet can optionally deliver to users of its collimators the test set to be used to verify collimator performance according to method described in point no 3. This option is particularly useful for situation when collimator is a part of test system in institution that implemented quality systems (ISO 9000 type).

10. WORKING TEMPERATURE

Typical CDT collimators are optimized to work at laboratory conditions: ambient temperature from about +10ºC to about +30ºC (optimal range is from +19ºC to about +25ºC). However, Inframet can deliver customized CDT collimators capable to work at temperature chambers: ambient temperature from about -40ºC to about +70ºC.

11. FEATURES

Main features of CDT collimators are listed below:

- Wide range of optical aperture of available collimators from 60mm to 300 mm (option up to 500mm). Virtually all imagers or multi sensor systems can be tested using collimators having optical aperture in this range.
- Several grades of manufacturing accuracy (quality of images projected by the collimator) It is possible to optimize collimator design (cost) to requirements of specific applications.
- Athermal design resistible to ambient temperature changes. The collimator can be used in a wide range of ambient temperatures. Typical range is from +5ºC to +40ºC but can be extended.
- Expanded quality control of manufactured collimators. Three stage quality control is used to assure manufacturing collimators that fulfill offered specifications.
- All CDT collimators are equipped with internal baffles and coated using paint of ultra low reflectance. This solution enables to eliminate unwanted reflected radiation inside collimators.
- Real measurement data of collimator resolution are presented. Not misleading claims that collimator is diffraction limited without precise information about true collimator resolution presented in numbers.
- Wide range of possible coatings to be used for mirrors used in CDT collimators.
- Special recalibration set is offered to users of Inframet collimators. This set can be used to verify in some temporal intervals if the collimator does not influence accuracy of measurements done with a test system. This recalibration set is particularly useful in institutions that implemented quality systems and must present their equipment to audits.
- Long life time of CDT collimators. This parameter depends on environmental conditions but typically life time of CDT collimators is in range of 10 to 20 years (without recoating).
- Open policy of Inframet that present detail information about CDT collimators in form of expanded data sheet. Potential users of CDT reflective off axis collimators can learn details of collimator design, performance, test methods and then make decision about possible purchase of the collimator. Inframet treats potential buyers of CDT collimators as long terms partners and do not try to get short terms advantages from offering only limited information on collimators.

12. VERSIONS

Inframet offers a long series of CDT collimators of different aperture, focal length, resolution (mirror accuracy), FOV and dimensions. Detail information about available versions is presented in Table 2.

Attention: this table presents values of values of collimator resolution measured during quality tests. Please note that these values are reduced due to limitations of test system. The limitations are negligible for collimators of SR/HR class but are significant for collimators built using UR class mirrors. It can be estimated that true resolution for UR class collimators can be even 50% higher comparing to values in table below.

Table 2. Versions of CDT series collimators

Code	**Aper-ture** [mm]	**Focal length** [mm]	**Resolution** [lp/mrad]			**FOV** [º]	**Dimensions [mm]** *approximate values*
			SR class	HR class	UR class*		
CDT460	40	600	≥5	≥60	≥90	4	610x140x210
CDT860	80	600	x	≥80	≥100	2.4	610x180x210
CDT1050	100	500	x	≥80	≥140	3.3	1050x180x250
CDT11100	110	1000	≥30	≥110	≥140	3.3	1050x180x250
CDT12100	125	1000	≥35	≥120	≥150	3.3	1150x190x260
CDT15150	150	1500	≥40	≥130	≥180	2.3	1530x250x320
CDT15120	150	1200	x	≥130	≥180	2.8	1230x250x320
CDT20200	200	2000	≥50	≥140	≥200	1.7	2100x300x360
CDT20160	200	1600	x	≥140	≥200	2.2	1610x300x360
CDT25250	250	2500	≥ 50	≥180	≥260	1.4	2610x350x400
CDT25200	250	2000	x	≥180	≥260	1.7	2110x350x400
CDT30300	300	3000	≥55	≥180	≥320	1.1	3110x410x490
CDT30200	300	2000	x	≥180	≥320	1.7	2100x410x490
options							
CDT35200	350	2000	x	≥180	≥350	1.6	2200x450x540
CDT35350	350	3500	x	≥180	≥350	1.6	4000x450x540
CDT40240	400	2400	x	x	≥400	1.4	2600x510x590
CDT40400	400	4000	x	x	≥400	1.0	4300x510x590
CDT45500	450	5000	x	x	≥400	0.9	5500x510x590
CDT50300	500	3000	x		≥400	1.1	3400x610x690
CDT50500	500	5000	x	x	≥400	0.8	5300x610x690
CDT60600	600	6000	x	x	≥400	0.8	6400x610x790
CDT-X	Different collimators on special request						

12. CODES

Code is composed from three parts: CDT – name of collimator type, number that gives information about aperture and focal length in cm units, and two letter part (SR, HR, UR or SQ) that gives information about collimator resolution (mirror manufacturing accuracy).

Example: CDT20160HR – CDT type collimator of 20cm aperture, 160cm focal length, and HR class resolution.

Version 5.8

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