INASAN's experience to build 1 m wide field telescopes. A proposal to build 1 m telescope with field of view of 12 square degrees and 9×9 k CMOS detector for Maidanak observatory.

Shugarov Andrey
Institute of Astronomy of the RAS, Moscow, Russia shugarov@inasan.ru

Toward the global network of 1 m class telescopes

In the last decade, wide field telescopes, as well as the networks of wide field telescopes, have made it possible to solve fundamentally new scientific tasks:

- Near Earth Object Program: all-sky survey to search for 10 m-class impactors to provide a warning time of 1-2 days before its possible collision with Earth
- Populations of small objects in Solar System, asteroids and comets
- Space debris, etc.
- Observations of gravitational wave sources counterparts
- Transiting exoplanets
- Gravitational lensing and Microlensing events
- Cosmology Investigations with Variables & Explosive Transients
- Supernovae
- Gamma ray bursts
- AGN / QSO variations
- Young and active stars
- Low-Mass Stars, Brown Dwarfs and Young Stellar Objects
- Stellar Transit Survey
- Structure of the Milky Way and Local Group Constraining
- Dark Energy with wide-field optical photometric survey
- Search for electromagnetic counterparts to neutrino events

Toward the global network of 1 m class telescopes

We believe, that a global network of 1-2 m aperture wide field of view ($w > 3^o$) telescopes will be the most universal and cost-effective instrument for various scientific tasks.

In 2021 INASAN applied for funds to build 3 modern 1 m class survey telescopes.

We suggest to install one of these telescopes at the Maidanak observatory.

Excellent astroclimate of the Maidanak site will allow to observe the entire sky up to 20^m-21^m every few days.

Maidanak may become one of the key observation points of the international BRICS Intelligent Optical Transient Network.

Minute and Resolutions of the Fourth Meeting of the BRICS Astronomy Working Group (31 October 2018)

. . . After deliberating on the report from the task team, the BAWG adopted the following three thematic areas for further development towards proposals:

a. Optical transient network

b. Neutral Hydrogen / 21 cm cosmology

c. Big data infrastructure collaboration towards Square Kilometre Array (SKA), Large Synoptic Survey Telescope (LSST) and other future large-survey projects

In 2020 a BRICS astronomy flagship proposal

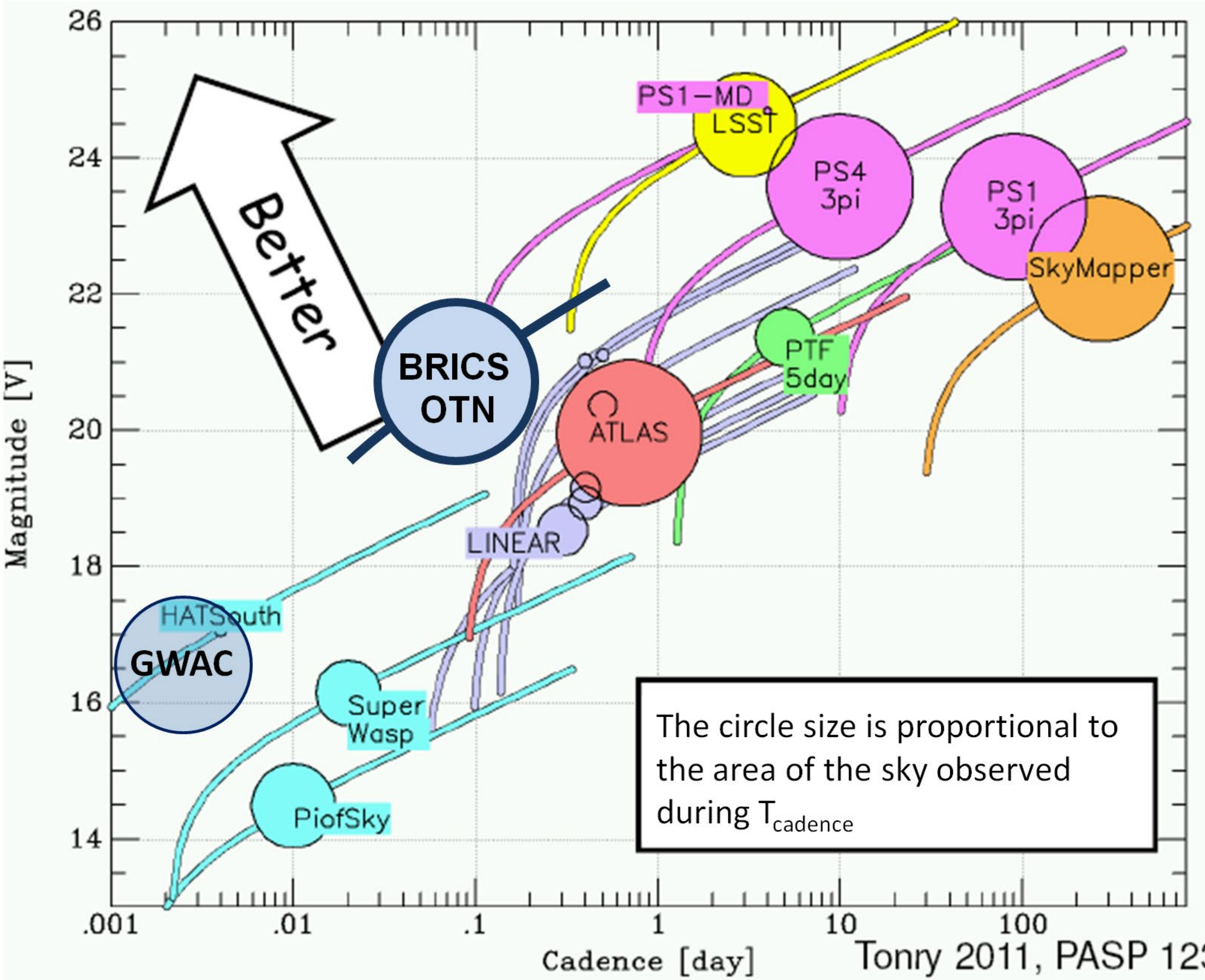
The BRICS Intelligent Telescope and Data Network (BITDN)

Lead Investigator David A. H. Buckley

South African Astronomical Observatory, South Africa

was selected for implementation.

BRICS Optical Transient Network on survey merit diagram



The circle size is proportional to the area of the sky observed during $T_{cadence}$

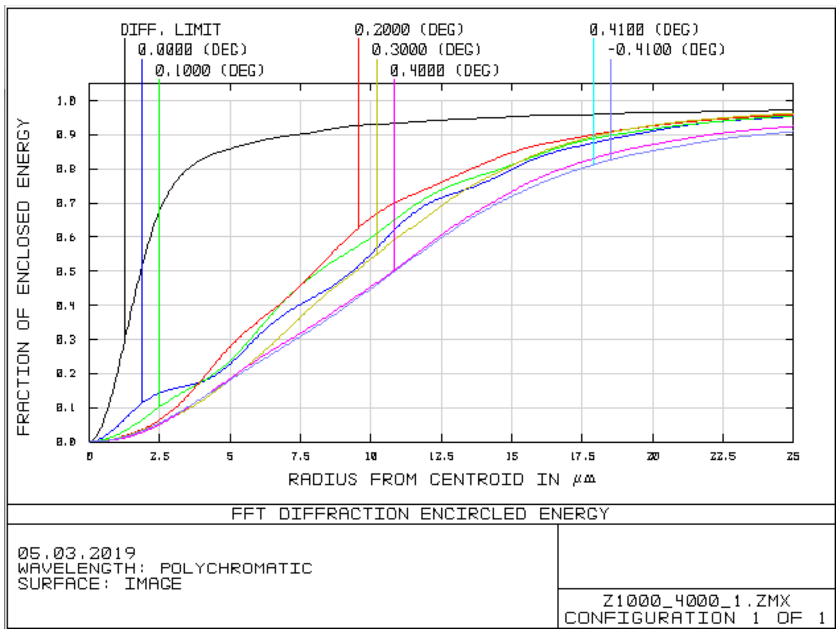
Tonry 2011, PASP 123, 58

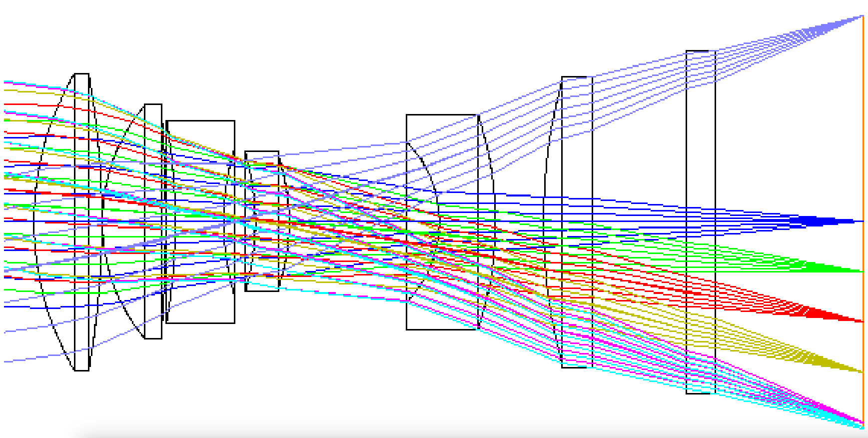
Focal reducer for Zeiss 1000 telescope (Simeiz), 2021.

INASAN has experience building a focal reducer for the Zeiss 1000 telescope at Crimean Observatory. We got the first light in spring 2021.

FoV	0.8 deg
	50 × 50 mm
Limiting magnitude	20^m
Filter wheel	FLI CL1-10
Filters	UBVRI

- FLI PL 16803 or ELSEi 2048 2048 BI DD MU2
- 60 mm detector with small pixels is the best option





INASAN experience with 1 m wide field telescope AZ1000WF

In 2013-2017 the INASAN's first 1 m class telescope AZ1000WF was built.

At that time it was one of the best price/performance ratio wide field telescopes.

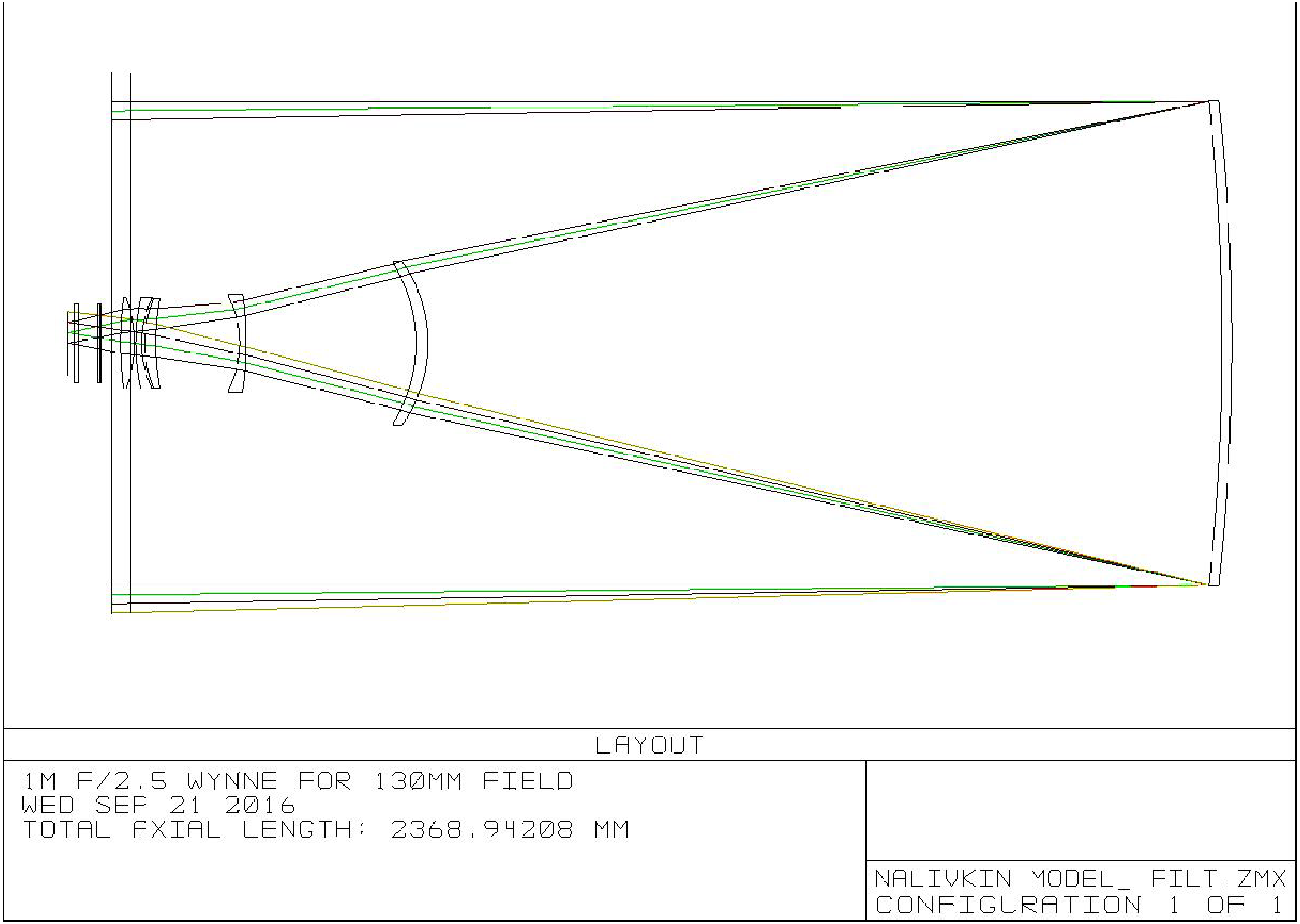
The main telescope parameters are:

- Aperture – 1 m
- Fast direct drive mount (10 deg/s)
- FoV – 3 deg (130 mm diagonal)
- Designed for 10×10 k CCD detector
- Limiting magnitude – 21.5^m
- Half-sky survey in two days down to 20.5^m

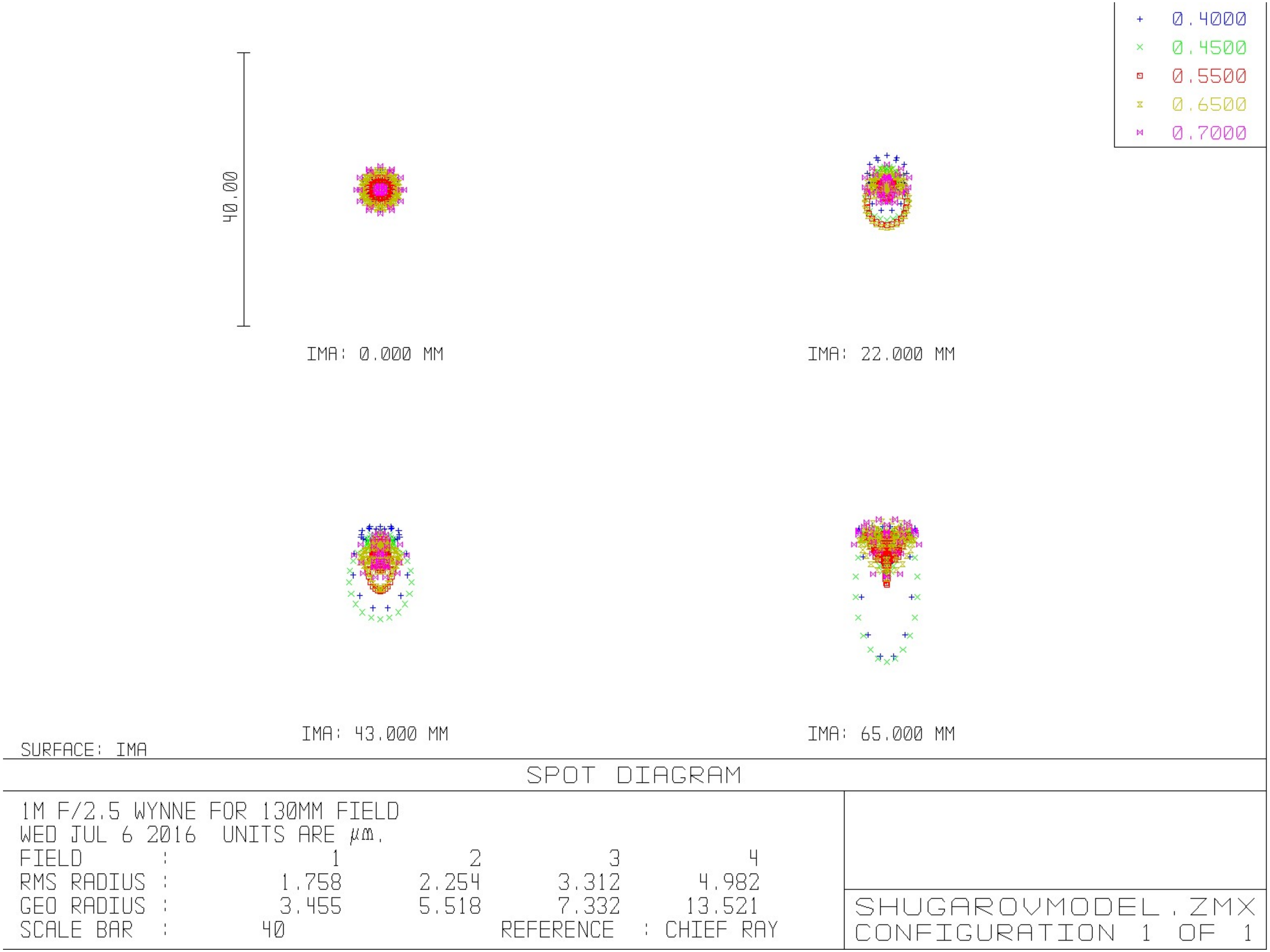
The first light was successfully obtained in 2017.

AZ1000WF telescope at Zvenigorod observatory, 2017.

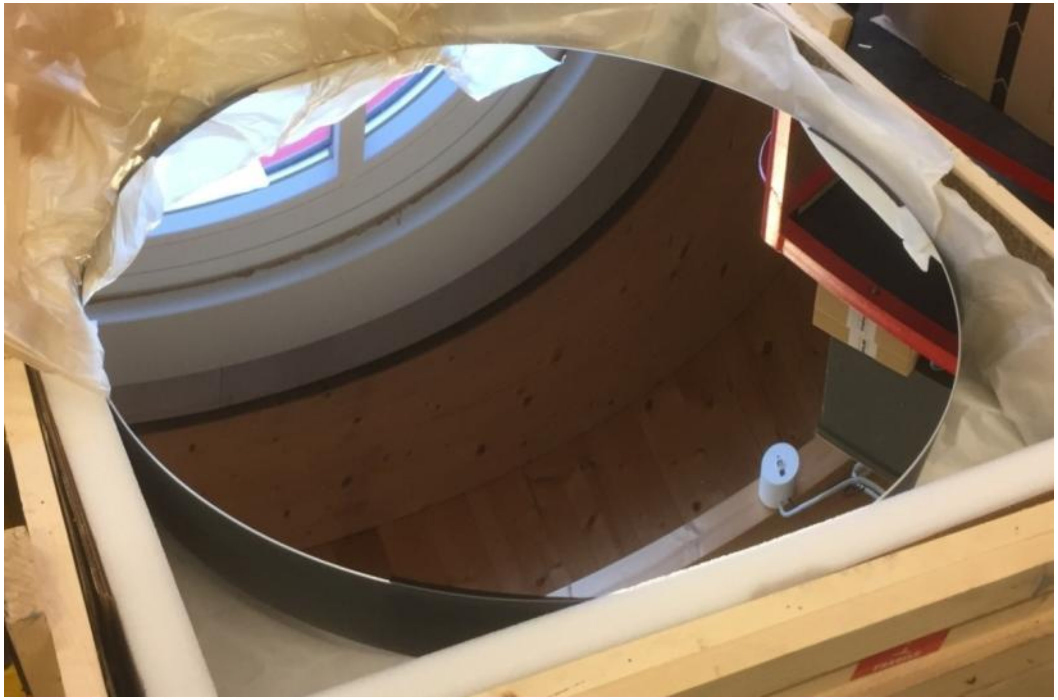
AZ1000WF telescope optical scheme



AZ1000WF telescope optical quality

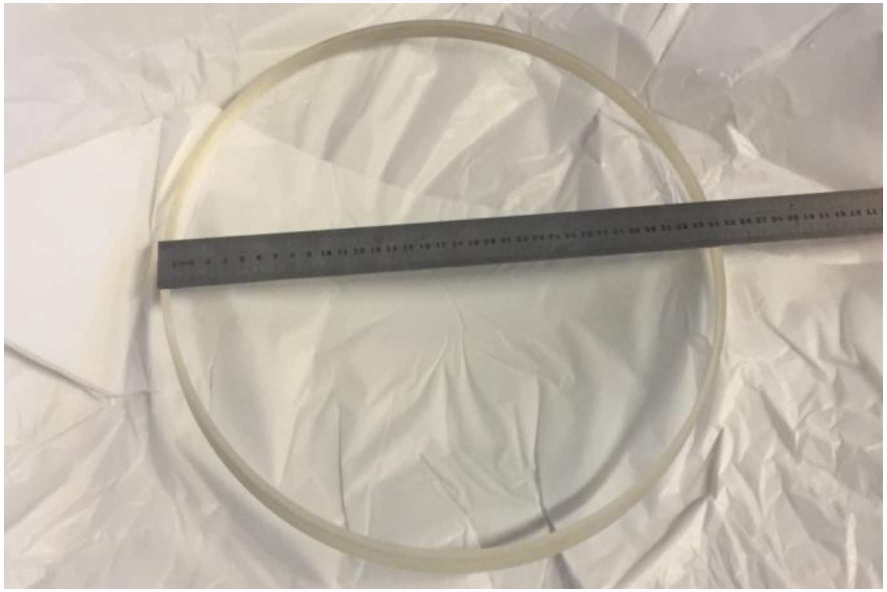


AZ1000WF telescope optical elements



Primary mirror was produced in Russia (TYDEX)

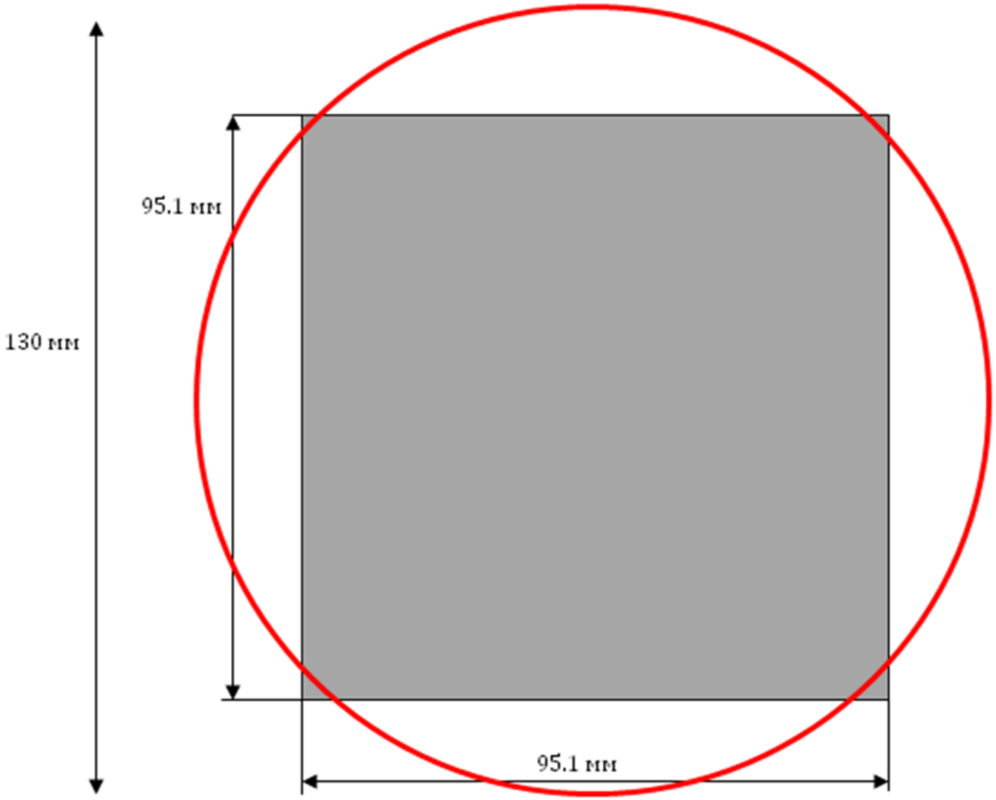
Lens corrector optical elements were made in Europe

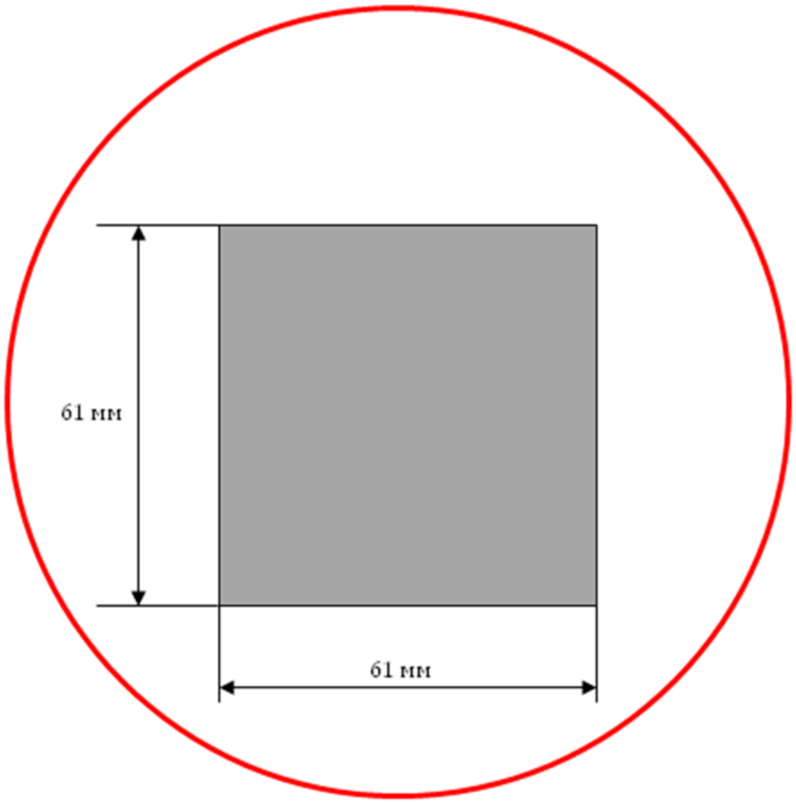


Detectors for AZ1000WF telescope

Parameter	Telescope	Spectral Instruments 1110S	ANDOR iKon-XL
CCD type		STA1600	CCD230-84-1-145 AR
Field of view, sq. deg	**6.93**	**4.72**	**1.97**
Photosensitive area, mm	130	95.1 × 95.1	61.4 × 61.4
Detector field of view, % of telescope FoV	100	68.1	28
Detector field of view		**2.1 × 2.1**	**1.4 × 1.4**
Scale, arcsec/pixel		0.74	1.23
Pixel format, kpixel		10.5 × 10.5	4 × 4
Number of pixels, million		111.7	16
Readout noise, e- rms		10 / 4.5	4 / 20
Peak quantum efficiency, %		90	90
CCD output ports		16	4
Readout time, s		70 / 10	40 / 1
Cooling		Cryotiger	Peltie, air / liquid
CCD temperature, ^{o}C		-100	-50 / -75

Detectors for AZ1000WF telescope



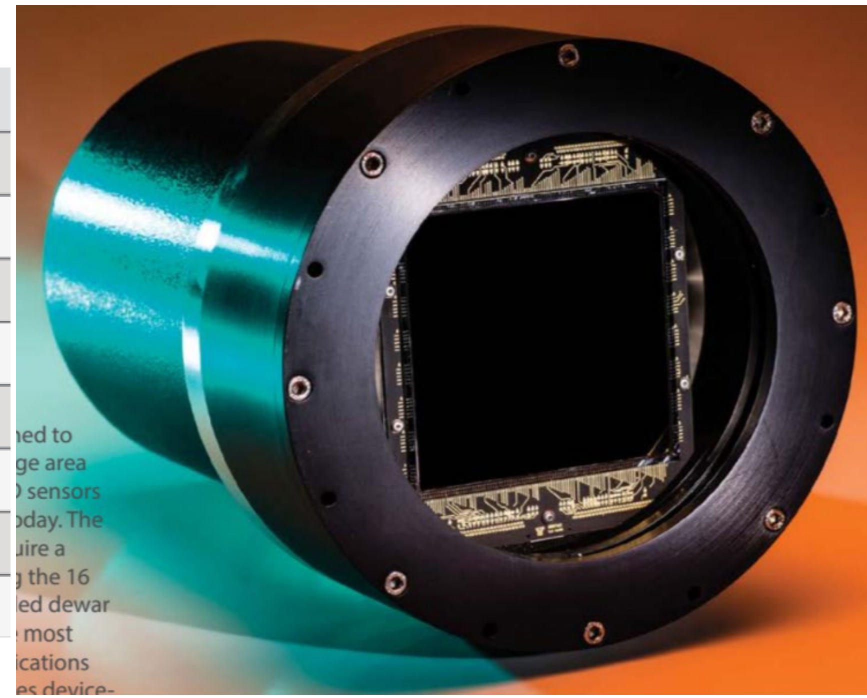


Spectral Instruments 1110S (USA)
STA 1600
95 × 95 mm
10k × 10k   9 µm pixel

ANDOR iKon-XL 230 (UK)
CCD230-84
61.4 × 61.4 mm
4096 × 4112 15 µm pixel

10×10 k CCD camera for AZ1000WF telescope

Typical Camera Performance With An STA 1600 CCD	
Typical read noise 100kHz	4.5e-
Typical read noise 800kHz	9.8e-
Dark Current	0.001e-/pixel/sec
Non-linearity	<1%, 200e- to 100ke-
CCD size	95.04mm x 95.04mm
CCD pixel size	9.0 µm
CCD pixel dimension	10560 x 10560
AR coatings available	Blue and Broadband



4×4 k CCD camera for AZ1000WF telescope

ANDOR iKon-XL 230 (UK)
CCD230-84
61.4 × 61.4 mm
4096 × 4112 15 μm pixel

Filter & shutter unit for large single-chip camera (120×120 mm)

Main functionality

- Mechanical shutter
- Liquid Crystal shutter (Optional)
- Filters
- Camera adjustment
- Precise timing control
- Camera mechanical protection
- Cable holder for derotator

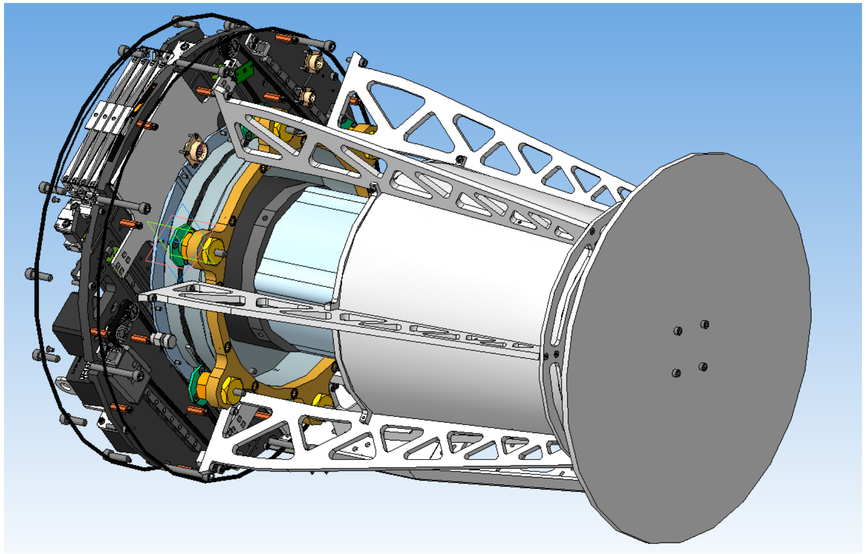
Main parameters

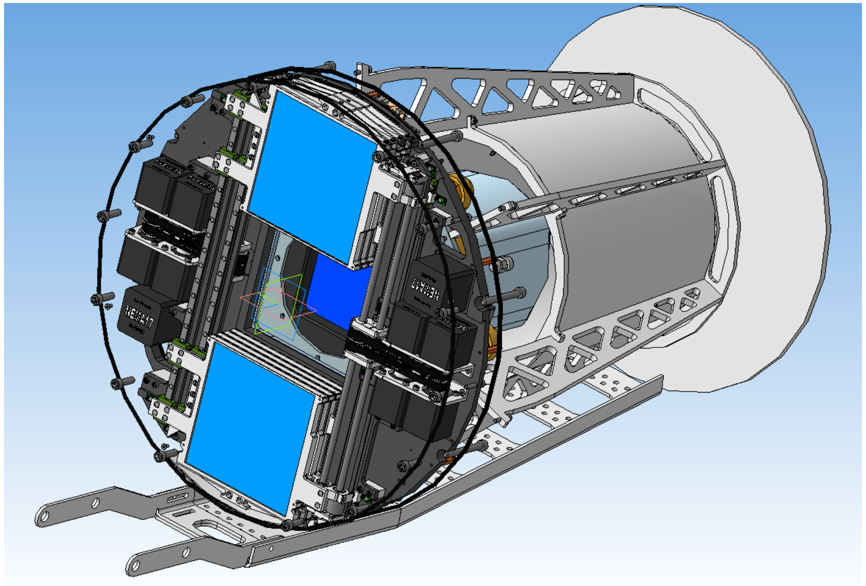
- Up to 8 filters of 120×120 mm
    - 1x neutral
    - 3x B,V,R
    - 1x quadrant
- Filter change time: 5 s
- Mechanical shutter exposure: >1 s

Supplier: Astrosib, Russia

Filter supplier:

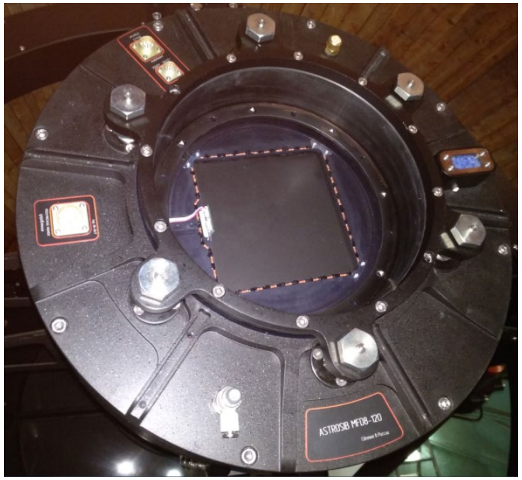
- Elektrosteklo, Russia





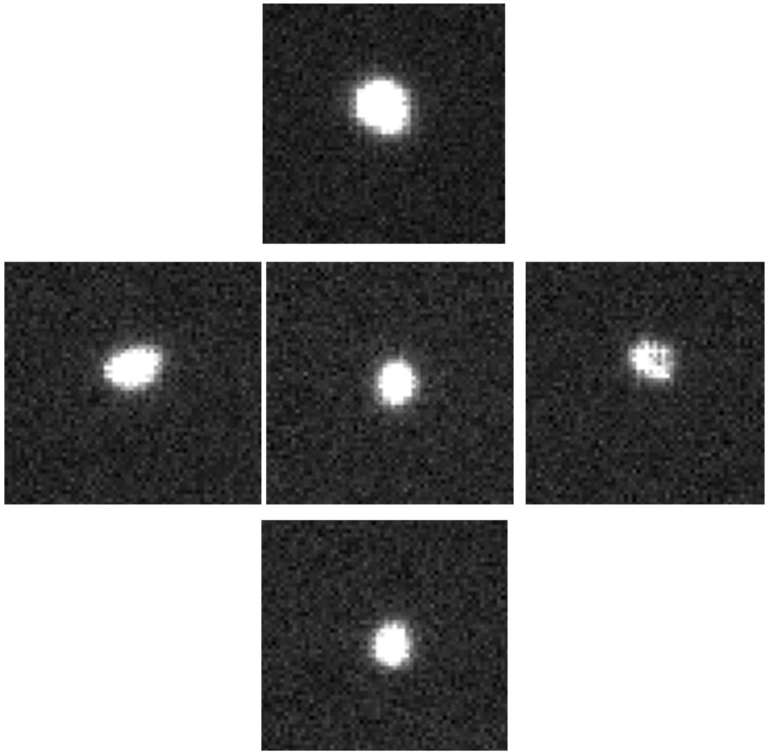
Filter & shutter unit with ANDOR iKon-XL camera

Filter & shutter unit on the telescope



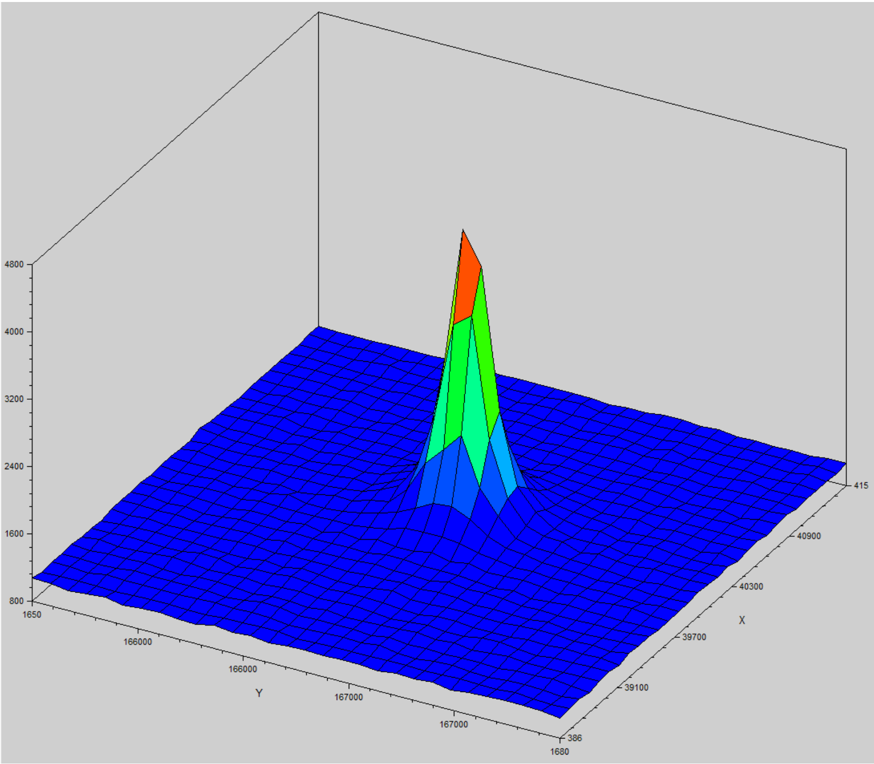
AZ1000WF telescope first light

Factory test (center, edge)



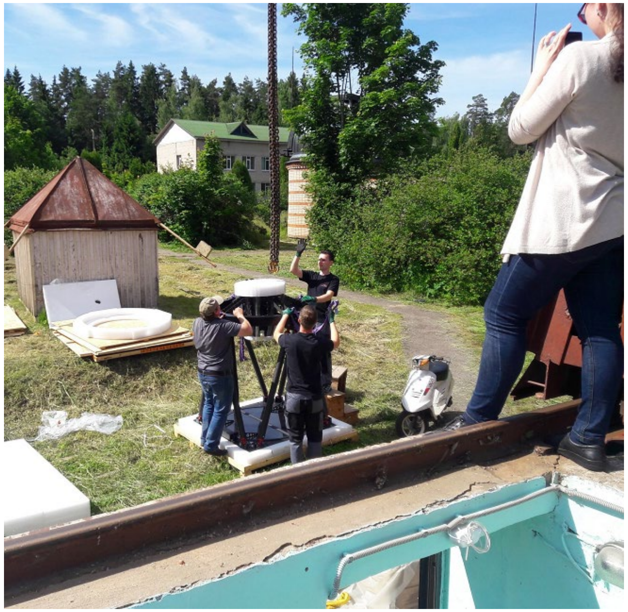
ASA AZ1000WF, 29.05.2017,
Galgenau, Austria
Bad weather conditions,
2 arcsec seeing

On-site test



ASA AZ1000WF, 3.07.2017
Zvenigorod observatory
Moderate weather conditions
Best FWHM is 1.6 arcsec,
average is 2 arcsec

AZ1000WF installation at Zvenigorod observatory (2017)



A new generation ASA EQ1000WF F:1.3 wide field telescope

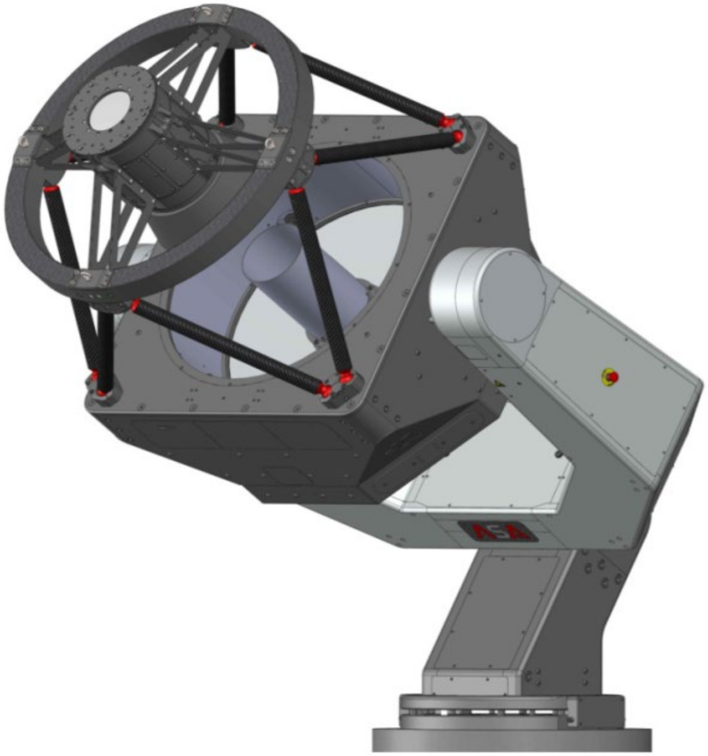
A new EQ1000WF F1.3 telescope was designed by ASA Astrosysteme GmbH.

The first telescope is being built for RSA to be a part of the BRICS Intelligent Optical Transient Network.
The delivery is scheduled for 2022.

Thanks to a new advanced lens corrector, the field of view on a **90 mm size detector** has been increased up to **11.6 sq. deg** without the need to use a full-aperture lens corrector.

The back focus of 65 mm allows the use of a filter change mechanism with up to 6 filters of 120 mm size.

An upcoming 9×9 k format (90 mm size) CMOS from Chinese company GPIXEL can reduce the dead time between exposures down to 3 s and improve sensitivity of the telescope because of the low readout noise (5 e^-) in comparison to a classical CCD of the same size.



ASA EQ1000WF F:1.3
general layout

A combination of a new fast focal ratio (F:1.3) wide field 1 m telescope EQ1000WF F1.3 and a fast 9×9 k CMOS sensor is an efficient way to build a cost-effective survey system with >20^{m} sensitivity.

Comparison of AZ1000WF and upcoming EQ1000WF telescopes

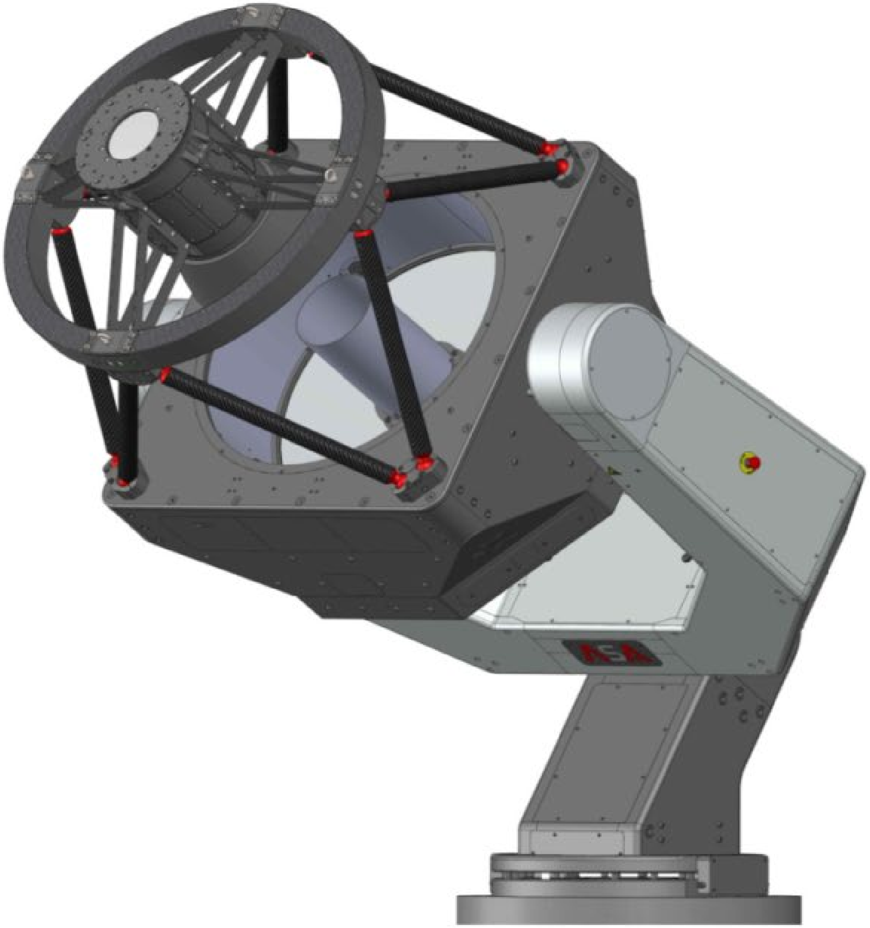
Parameter	AZ1000WF	EQ1000WF F1.3
Aperture, mm	1000	1000
F-ratio	F:2.5	F:1.3
Focal length, mm	2500	1300
Spectral range with best quality, nm	400-700	400-850
Full spectral range, nm	-	370-1000
Back focus, mm	100	65
Field of view, deg	2.97	3.84
Field of view, mm	130	87
Field of view, sq. deg	6.93	11.6
Field of view on detector 61.4×61.4 mm, deg	1.4×1.4	2.7×2.7
Field of view on detector 61.4×61.4 mm, sq.deg	2	7.2
Field of view on detector 89.04×91.78 mm, deg	$\boxed{2\times2.1}$	$\boxed{3.9\times4.1^*}$
Field of view on detector 89.04×91.78 mm, sq.deg	$\boxed{4.2}$	$\boxed{11.6}$
Central obscuration, %	-	15 on the edge
D_{80}, μm	8-15 center-edge	8/18 asph./sph.
Scale, arcsec/pixel 10 μm	0.82	1.59
Primary mirror material	Sital	SiO_2
Mass, kg	2400	1850
Height, mm	-	3100
Dome diameter, m	6	6
Mount	Alt-Az	Equatorial

(*) Only part of the detector is used

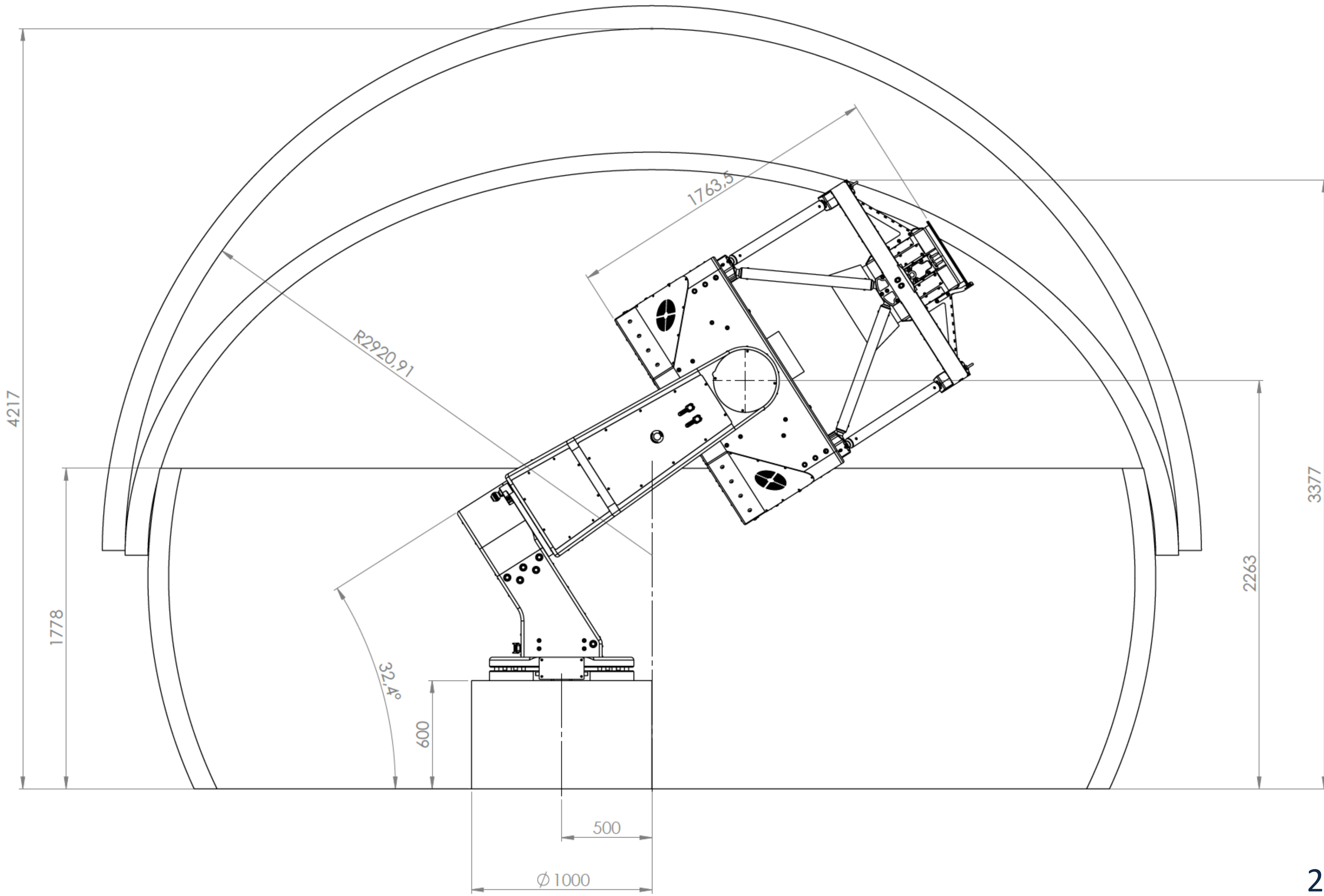
ASA AZ1000WF
INASAN, Zvenigorod, 2017.

ASA EQ1000WF F1.3
Being built for RSA,
delivery in 2022.

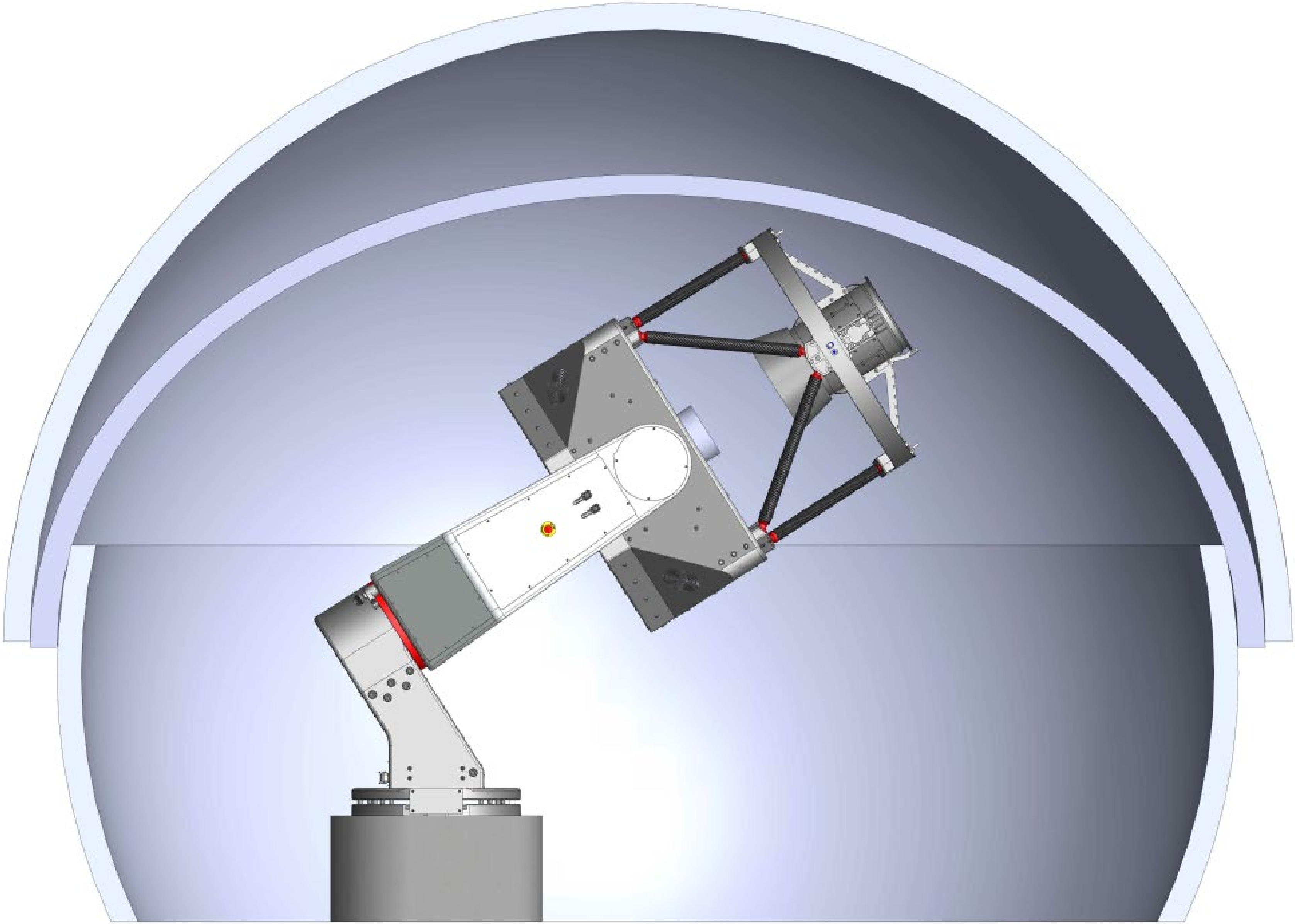
A new generation ASA EQ1000WF F:1.3 wide field telescope



1 m EQ1000WF telescope in 6 m dome



1 m EQ1000WF telescope in 6 m dome



Single-chip 9×9 k (90 mm) CMOS

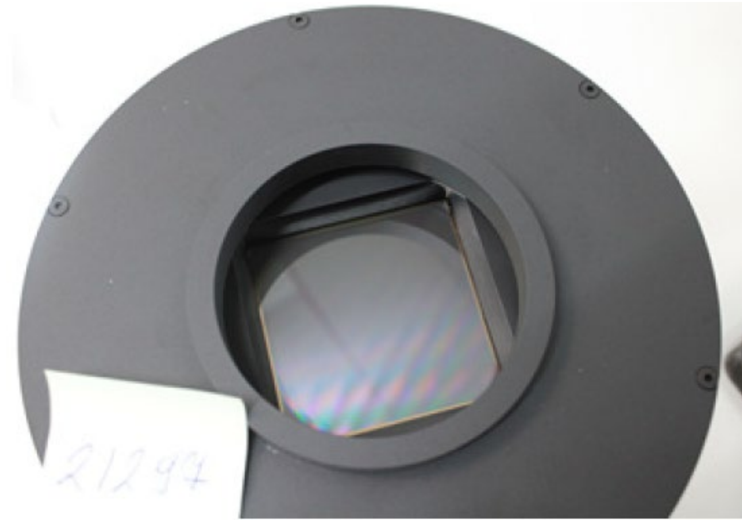
At the end of 2021, a new large 9x9k CMOS of the Chinese company GPIXEL is expected to be released.

Preliminary characteristics:

• Photosensitive area	89 × 91.20 mm
• Pixel size	10 × 10 μm
• Number of active pixels	8900×9120
• Peak QE (BSI)	>95%
• Full well	90000 e^-
• Readout noise	5 e^-
• Readout speed	0.3 fps Full frame

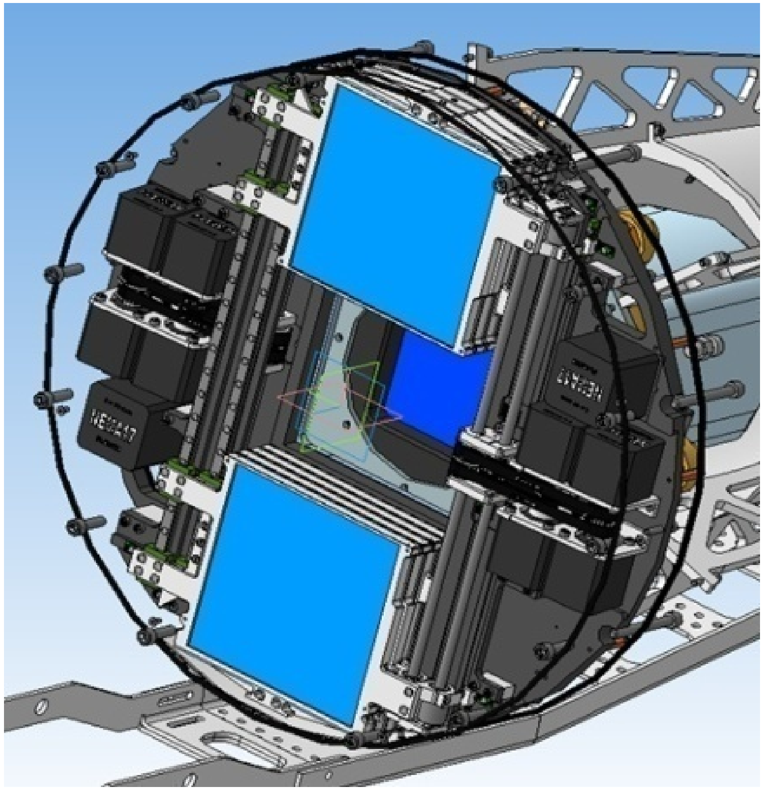
The Russian company "NPK Photonika" is ready to develop a TEC-cooled camera NEVA9090 based on this new 9k CMOS.

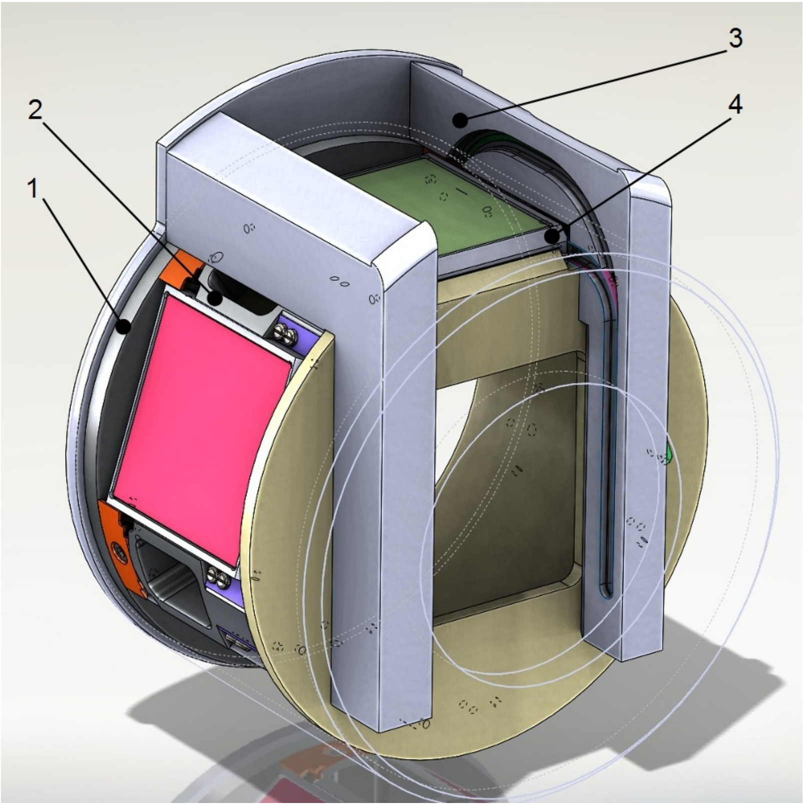
The heritage of the NEVA6060 camera based on 6×6 k GSENSE6060 CMOS will be used.



NEVA6060 CMOS camera
of 6×6 k format.

Filter unit





Reciprocating movement design

8x 120 mm square filters
(heritage from AZ1000WF telescope)

Outer diameter ~420 mm
(leads to a small vignetting)

Design: Astrosib

Coaxial design (concept)

M. Nalivkin (INASAN)

More complicated design,
avoids additional vignetting

Conclusion

Currently, more and more wide field telescopes are being put into operation in the world. However, the task of a daily survey of the entire available celestial sphere with a sensitivity deeper than 20^m has not yet been solved due to the lack of available medium-aperture (about 1 m) telescopes.

To build such a network, it is necessary to implement new technologies in order to achieve better performance, primarily in terms of increasing the field of view. On the other hand, it is necessary to keep the complexity and cost of a single node within a reasonable limit.

INASAN has experience building a wide field survey telescope AZ1000WF with an aperture of 1 m, field of view of 3 degrees in diameter (130 mm) and 10×10 k format CCD camera with a field of view of 4 square degrees.

A new 1 m EQ1000WF F1.3 telescope was designed by ASA Astrosysteme GmbH. The field of view is **11.6 sq. deg with a 9×9 k CMOS camera**.
The first telescope will be delivered in 2022 for RSA.

INASAN has applied for funds to build 3 of such telescopes.
We suggest to install such a telescope at the Maidanak observatory. An excellent astroclimate will allow to survey the entire sky up to 20^m-21^m every few days.
Maidanak may become one of the key observation points of the international BRICS Intelligent Optical Transient Network.

The research was carried out with the financial support from the RFBR in the framework of the scientific project No. 19-29-11013.