Special Camera System for Solar Eclipse observation

Ing., Lukáš, Marek

1. Annotation in Czech Language.

Pozorování úplných zatmění Slunce je činnost velice obtížná, neboť je tento jev velice zřídka viditelný. Přináší však cenné poznatky o dějích těsně nad slunečním povrchem, které nelze pozorovat ani z družice. Zeměpisná poloha pozorovacích míst a krátká doba trvání úkazu zadává mnohé požadavky na pozorovací systém. Důležitým požadavkem je však také další zpracování snímků. To vše vede na vývoj synchronizovaného systému 7 kamer s patřičnou úrovní ovládání. Projekt dostal krycí název "sedmihlavá saň".
V článku nejprve popíši prvotní návrhy a koncepci přístroje. Byl již vyroben 1 exemplář objektivu pro pozorování a testován během zatmění Slunce v Egyptě v březnu 2006. Tento prototyp nesplnil zcela požadavky proto se hlavně zabývám jeho novou verzí. Také zde je uvedeno řešení pohonů celého systému za požití nejmodernější techniky.

2.1. Why to observe Solar Eclipse from the Earth?

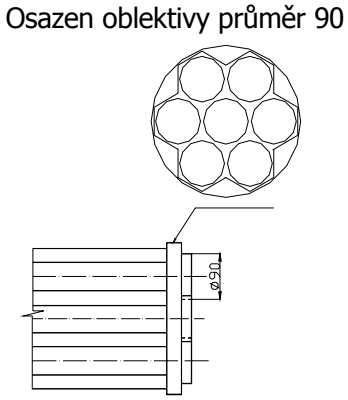
The Sun is main Manufacturer of Energy for whole its Planetary system. Processes on the Sun and its Atmosphere affect many Actions in the Earth. Very long ago People believe that the Sun is God or divine Instrument. First Observing of Solar Eclipse is date to Old Chinese Dynasties.
First Systematic Observations of Solar Eclipse started at beginning of 19^{th} Century. In this Time, people became interested in Solar Physic. At first Time, the Scientists started to observe Protuberances. Than People recovered, that Solar Corona is stretching at interplanetary Space. However, nobody knows any Think about Physics of Corona and its Incidence to The Earth.
Because Brightness of the Sun is more intensive than Brightness of Solar Corona was until 1930 impossible to observe Corona except Eclipse of the Sun. In 1930 made B. Lyot first observation of Corona by his Coronographer. Today we have Observations of Corona made by Satellite SOHO in many spectral Lines. However SOHO can observe from 1.2 Radius of the Sun. Main Contribution of Observing Solar Eclipse is to interconnect Processes in the outer Corona and on the Sun Exterior.

2.2. Construction Requirements and why are them.

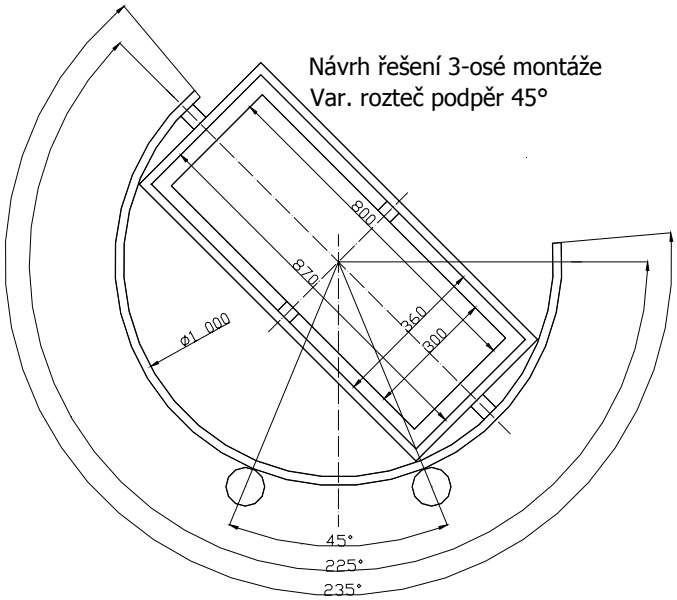
Total Solar Eclipse, which is most important, is Phenomenon sporadically possible to Observe. The Phenomenon takes maximally 6 Minutes and is observable at very small Territory.
Elaboration of Photos is made digitally with using statistic Software to highlight Dynamics of Brightness. Statistic Elaboration needs nearly 1000 Pieces of Photos.
Apparatus for this observing must have more than one piece of Camera and Objective. The Computer must control timing of Photos and Data Transfer. Locating and Sighting must be possible in all Geographical Latitudes. The System must be good transportable and easy demountable to Parts lighter than 20kg. In addition, it must be possible to energize only from Car Engine (12V). All Parts and Mechanism must guaranteed work without Corrosion in Temperatures from -40°C to 70°C and in very hot and salty or very freeze Air.

3.1. Preconstruction of a Stand.

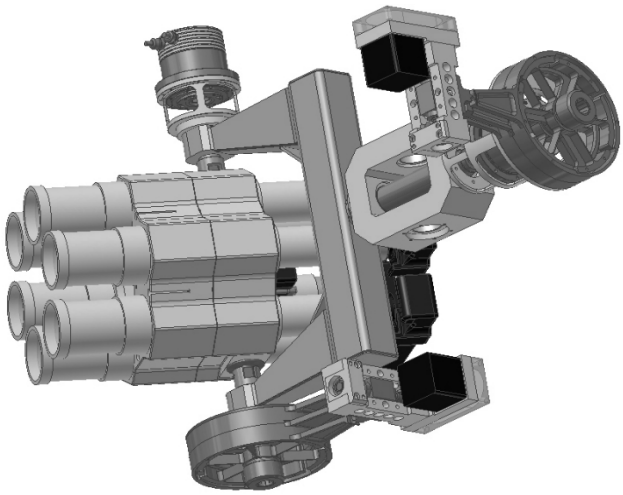
First, I had to make Conception of Apparatus. It will have seven independent Objectives with oven Cameras controlled on one Stand. Tandem of Objectives is sketched in the Picture 3.1.
For Stand are there two Possibilities with three-axis motion. My conception is to make it like rectangle frame Construction in C-Stand. C-stand is used for adjusting geographical Latitude. Both Axes of rectangle Frame are used for standard observing Guidance. That is sketched in Pic. 3.2.
Another possibility is to make it like fork-type of Mount with 3rd axis for adjusting geographical Latitude. This Version developed College David Šestak. In the Picture 3.3 is his semi finished Version staffed by perversions of Objectives.
Hereafter I will describe next Design of frame Construction in C-Stand. It could have been manufacture for Observing.



Pic. 3.1: Tandem of Objectives.



Pic. 3.2: Rectangle frame Construction in C-Stand, first conception.



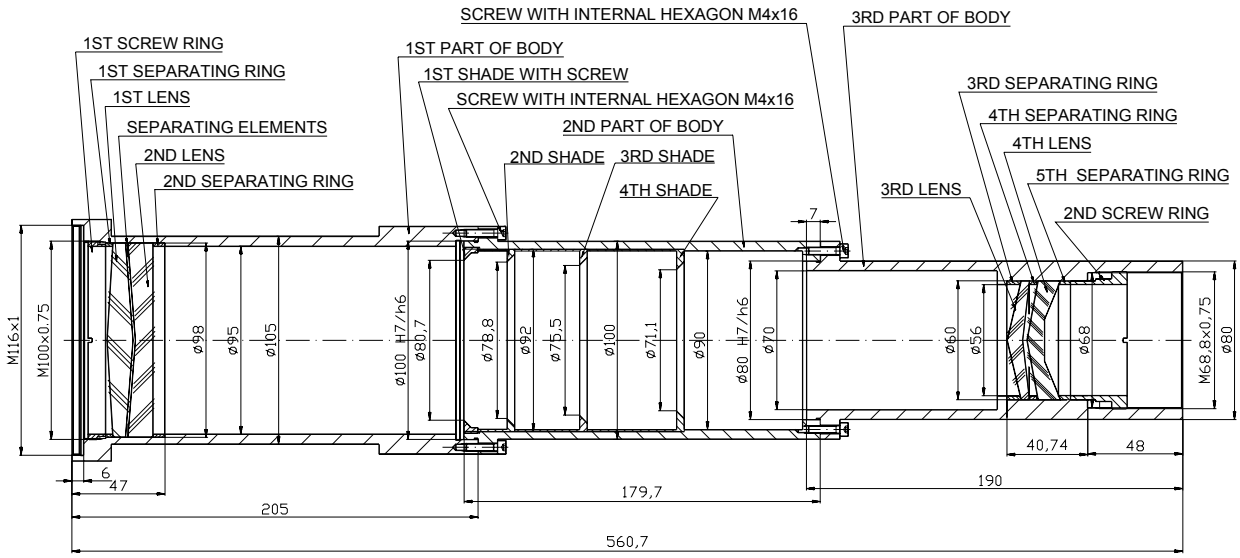
Pic. 3.3 Fork-type of Mount without 3rd axis. Precision Adjusting is realised by deformed Body.

3.2. Preconstruction of one Prototype of Objective.

For recording of Data is used Camera Canon EOS 20D. Optical Parts of Objective designed and manufactured Optical Manufactory VOD AVČR in Turnov. Optic is designed to meet Requirement of radius of Picture of Solar Disk. Objective Parameters are Diameter D=100mm, Focus f´=550mm. My work was to design Body of Objective, its Stand and Mechanics.

There was problem to find and buy some Tube meets Diameter Requirement. So that I decided to design Body of Objective from three Tubes made on turning Machine. Precise Radiuses with six Male-Screws joint parts of Body. It makes possibility to clean interior of Objective and divide it to smaller Parts by Transport.

There is Screw M116x1 in entry Side of Objective for possibility of join any Filter in standard Bushing. Screw M68,8x0,75 at Output of Objective is to join commercial produced Focuser BORG with Reducer for Cannon Cameras. In middle Part of Objective are four Shades to absorb Spread Light. Lens in Objective are placed in precise Radiuses. Lens are pressed by Screw Rings and separated by separating Rings. Interior of objective is matt Black coloured and Exterior is White. Sketch of Objective is in the Picture 3.4 and complete Objective in Picture 3.5.



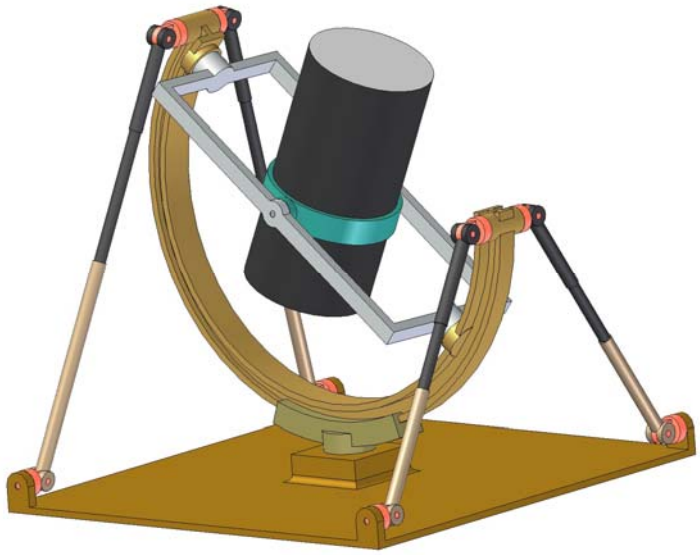
Pic. 3.4: Sketch of manufactured Objective.

Pic. 3.5: Photo of manufactured Objective before it was painted.

Just by Mounting, I find too much Spread Light in Objective, than on test Pictures. The objective was tested in March 2006, by total solar Eclipse in Egypt. There were found more problems than Spread Light by testing. One of them was too big Weight of it. That is why I decided to make another Construction of objective, used Carbon Composite.

4.1. The Stand and its Electronic Control.

How I mentioned upper, I will further work at Variant of rectangle Frame Construction in C-Stand. First Problem is motion of Objective-Tandem in C-Stand. This Motion must work precise by Observing, because it is Daily and Adjusting Movement.
Motion of Objective-Tandem in rectangle Frame is used like Adjusting Motion, it is declination Axis. Coarse Adjusting will be manual. Precise adjusting, I suppose max. ±2°, will be realised by deformed Body, same like in Picture 3.3, with precise Working Screw. There will be used Products of Firm MAXON. Accurate Setting of Axis will be controlled by 360° Incremental Sensor.
Motion of rectangle Frame in C-Stand is daily Motion, rektascenze Axis. Speed of this Motion must be precise 0.00666 rpm by whole 20 minutes observing. Coarse Motion will be realised by worm Gear and standard Motor (MAXON). Precise Adjusting and its Controlling will be the same like on Declination Axis.
Second Problem is how to realise precise adjusting of C-stand. Flat of C-Stand must be collinear with Earth Meridian and Angel of rektascenze Axis must be precise the same like geographical Latitude. In classic Composition must C-Stand been embattled in Underlay only by one big Bearing. That's why Bearing and C-Stand must be very sturdy.
There is Possibility to use principles of redundant Mechanisms and frame Structures. C-Stand and its Bearing can be very light, this is advantage for Transport. Necessity of precise Algorithm for adjusting is a Disadvantage.

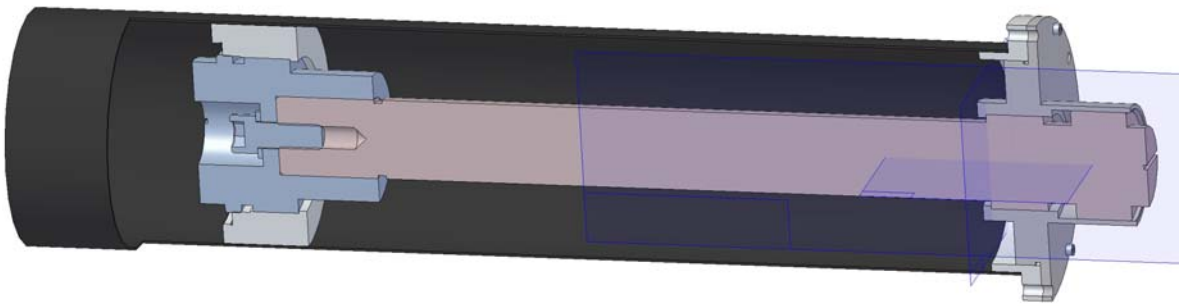


Pic. 4.1: Model of C-Stand with Shoring.

There are four Shoring with changeable Length on both Ends of C-Stand. The Shorring can be manufactured from Carbon Composite. Coarse Adjusting of Length of Shore is manual, Precise Adjusting can be manual also, but better is to use precise Actuator. There must be possibility of precise Reading of Length of Shore in both Variants. Model of C-Stand With Shoring is on Picture 4.1.

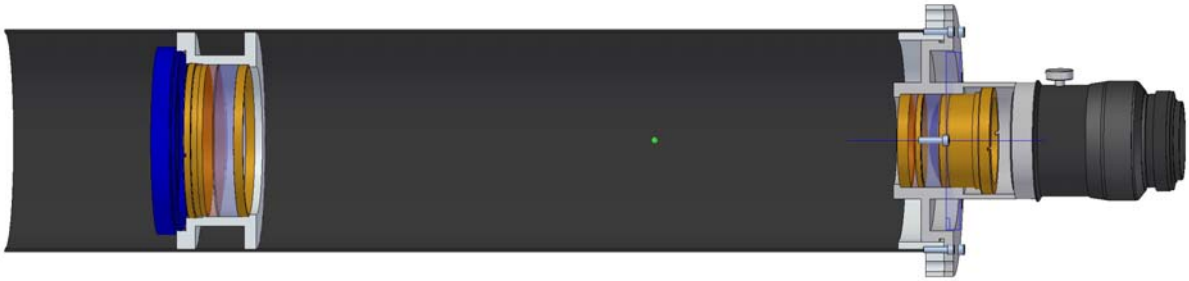
4.2. Final Version of Objective used Carbon Composite.

First Version of Testing Objective did not meat many Requirements well. So that I tried to Design better version used Advantages of Carbon Composite. Those are very low Weight and Possibility of affecting linear thermal Expansion.



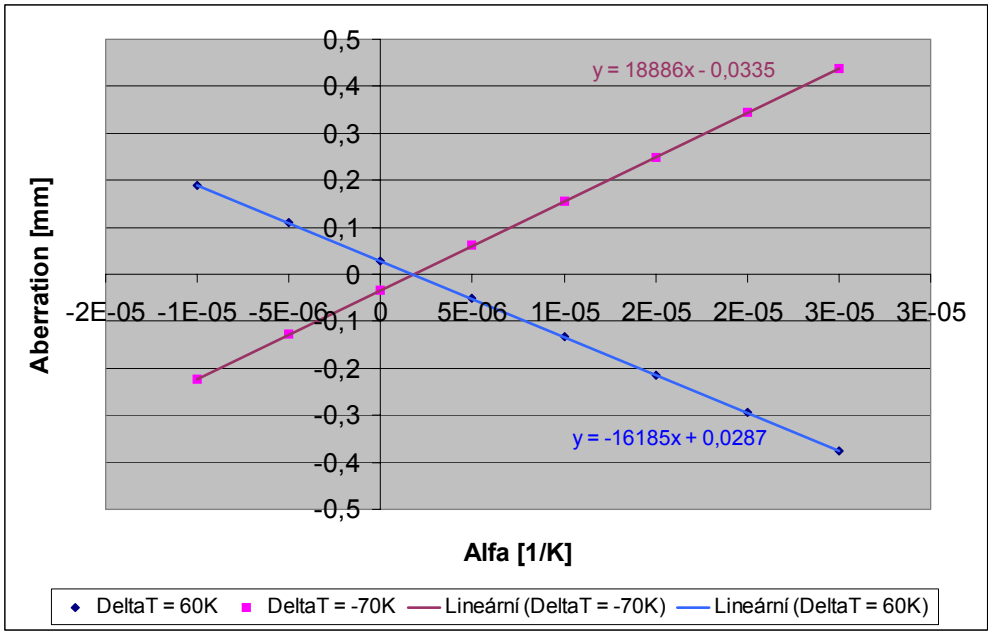
Pic. 4.1: Tool for precise Bonding.

Placement of Lens will be realised in two separated dural Bushings. Placement of Lens in each Bushing is the same like in old Version. There are Screws M116x1 on entry Side and M68,8x0,75 at Output with the same Function. There is the biggest Problem how to join each Bushings into carbon Tube and meat Requirement of Precise. So I had to Design some Tool for precise Bonding (Picture 4.2). Second Bushing is possible to divide and I can get into Objective. It has six Holes ∅7 to join Objective into Tandem, or into Reducer for any Stand. Weight of one objective with Camera I premise lower than 4.5 kg. Model of carbon Objective is on picture 4.3.



Pic. 4.3: Model of carbon Objective.

Finally I tried to count linear thermal Expansion meet Requirement of minimal Aberrations in very big Range of Temperatures. I suppose thermal Expansion of each Part and change of Radiuses of each Lens. Thermal Expansion of Carbon Tube is changeable Value. Range of temperature is from -50°C to +80°C. On Picture 4.4 is Diagram of Aberrations depending up to Thermal Expansion of Carbon Tube. Therefore, the best thermal Expansion is $1{,}77 \cdot 10^{-6} K^{-1}$.



Pic 4.4: Diagram of Aberrations depending up to Thermal Expansion of Carbon Tube. All for Temperatures -50°C and +80°C.

5. Conclusion.

Using Carbon Composites can contribute a lot in design of Astronomical Telescopes. Currently manufactured Carbon Tubes for Sport Equipments or for Printing-works are not too expensive, so that I hope them will be used maximally. But precise Motors from MAXON are very expensive, but the best for our Need. The biggest Problem is financing of The Telescope System. Many Parts of System will be delivered like Sponsoring and I hope That Telescope will observe soon.

6. Literature.

1. V. Rušin, M. Rybanský: Slnečná koróna. VEDA Bratislava, 1990
2. M. Hajn: Přehled přesné mechaniky. SNTL Praha, 1969
3. J. Bumbálek: Základy technické optiky. Vydavatelství ČVUT v Praze, 1995
4. MAXON Motors, Catalogue, 2007