AD1 - Holographic set-up Technical Specifications

"SETUP OLOGRAFICO PER LA REALIZZAZIONE DI VPHG DI GRANDI DIMENSIONI"

CIG: A034AE8768, CUP: C33C22000640006

PNRR-STILES IR0000034

Contents

1 Scope of the document

This document, which is an applicable document (AD) of the Statement of Work, contains the requirement specifications for the items necessary to build the large size holographic setup for making Volume Phase Holographic Gratings (VPHGs) with size larger than 400 mm in diameter and suitable for spectroscopic instrumentation of the Extreme Large Telescopes, i.e. ELT, GMT, TMT. VPHGs are dispersing elements widely employed in astronomical spectrographs characterized by large diffraction efficiency. They can be easily customized and they are produced using an innovative process.

2 Setup Description

The holographic setup consists in an optical bench hosting a high-power laser. The laser is split in two beams of equal power, which are passed through spatial filters. The diverging beams feed two off-axis parabolic mirrors (OAPMs), are collimated, and sent to the flat mirrors (FMs). A basic scheme of the setup is reported in Figure 1. The flat mirrors are mounted on rotating stage to set the desired interference angle, which determines the grating period and the position of the interference area on the optical bench. In this position, the glass substrate coated with the photosensitive laser is place for the laser exposed, as show in Figure 2. A suitable holder will be necessary to host the substrate and has to be mounted on rotating stages to set the slanting angle. The optical design is symmetric as respect to a vertical plane passing through the substrate; the vertices of all the elements are placed in a common horizontal plane, as shown in Figure 3.
The optical bench has an "H" shape in order to host the two couples of mirrors and to allow for the translation of the sample holder in the central region.

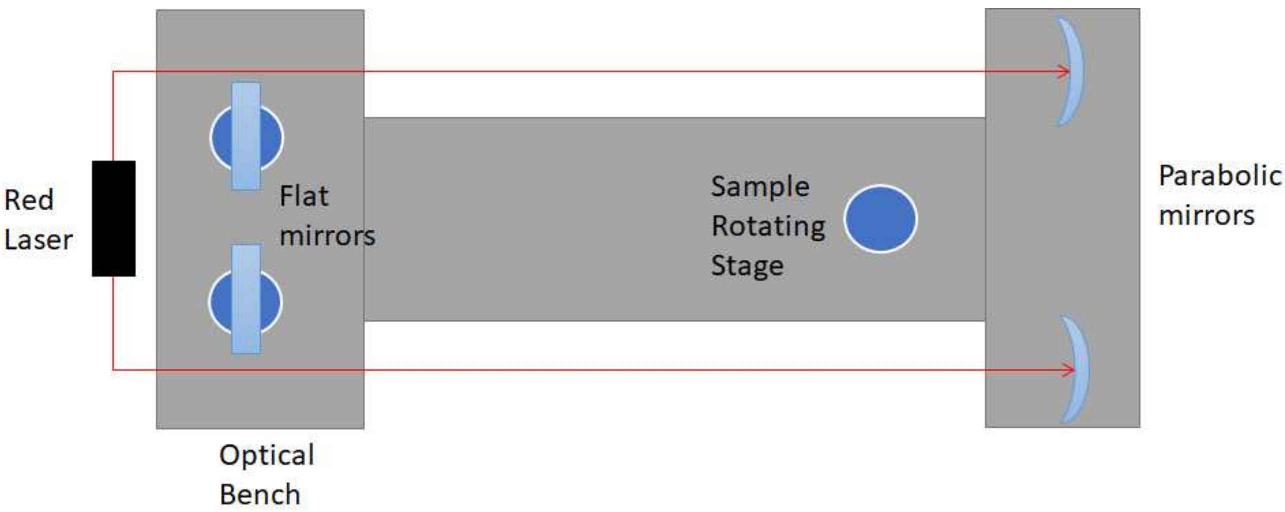

Figure 1: Scheme of the holographic optical setup with the main components

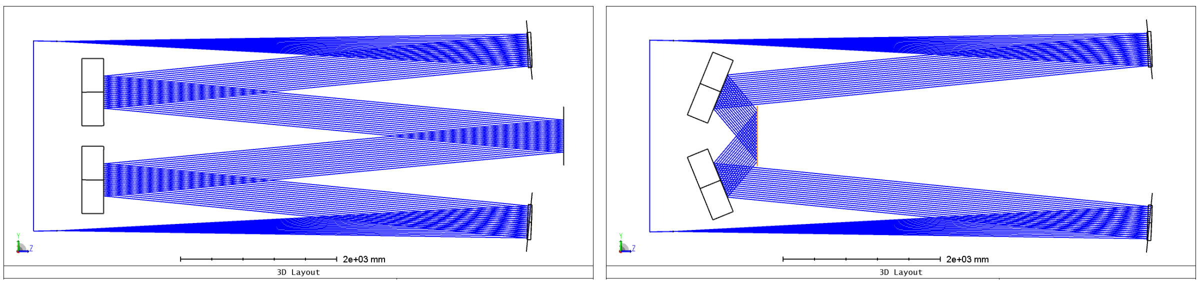

Figure 2: two possible configurations of the setup, top view. The flat mirrors are tilted to set the grating line density.

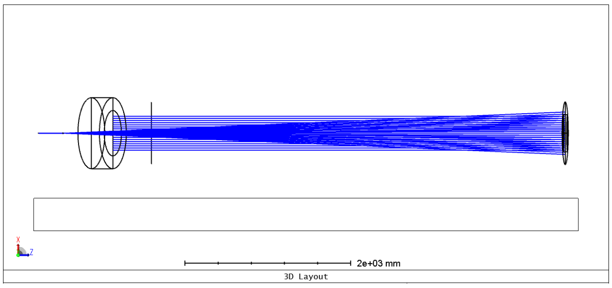

Figure 3: setup, lateral view to show the same optical center of the optical elements.

Based on the reported description, the components of the setup are the following:

- Optical bench;
- High power red laser;
- Two off-axis parabolic mirrors (OAPM) mounted on their optomechanics;
- Two identical flat mirrors (FM) mounted on their optomechanics;
- Two identical motorized high-precision rotating stages. The motorized stages are mounted underneath the flat mirrors and used to set the interference angle.
- One motorized high-precision rotating stage for hosting the substrate holder plus an optional one.

The optical table must be pneumatically isolated to assure the best isolation from floor vibrations. The H shape is necessary to host the large optics at a certain distance designed to have a certain line density range. The thinner central part must be accessible by the operators to place the photosensitive substrate mounted in a suitable holder, which will be different from VPHG to VPHG. The laser must be single mode TEM00 with a long coherence suitable for performing holography and emitting in the red to minimize the scattering effect in the photosensitive material. Moreover, the power must be high because the writing beam is very large and a certain power density is required to impress the photosensitive material and to transfer the grating pattern. The two OAPMs must have a small Wavefront Error (WFE) to minimize the aberrations in the final VPHG. The optical quality must be ensured when mounted on the suitable gimbal mechanics. Similar characteristics must be shown by the FMs. In addition, they are equipped with a high-accuracy motorized rotation stage. The stages will make possible to automatize the writing system and the high rotation accuracy is necessary to minimize the steps for achieving the target line density of the VPHG.

3 Specification table

The requirements for the different components are reported in the following tables. There are some OPTIONAL requirements (see Comment column); all the other requirements are **<u>mandatory</u>** to be admitted to the evaluation of the technical proposal.

<u>Optical bench</u>

An isolated optical bench is required to host the optical setup. The bench must have an "H" shape in order to place the reflective optics at the desired distance and the thinner central part to have access to the sample positioning (figure 1). The two sides of the H can be different because they host different optical elements. The details of the optical bench are reported in figure 4.

Req. #	**Type**	**Value**	**Comment**
OB-1	Material	Ferromagnetic steel	
OB-2	Shape	"H"	See the drawing in the section 4
OB-3	Lengths and widths	See drawings in figure 4	
OB-4	Total payload	> total weight of the items reported in this document + 200 kg	
OB-5	Bench thickness	>= 300 mm	
OB-6	Total height	900 – 1150 mm	
OB-7	Surface flatness	< ± 0.3 mm	
OB-8	Vertical positioning accuracy	< ± 0.3mm	
OB-9	Multiple bench	yes	The connecting system must preserve the properties of the single table (flatness and rigidity)
OB-10	Maximum single bench length	4000 mm	
OB-11	Active vibration isolation system	yes	Pneumatic system
OB-12	Resonance frequency	< 1 Hz	
OB-13	Type	Metric	
OB-14	Mounting Hole Type and Pattern	M6 holes with 25mm spacing	
OB-15	Table surface	Black	OPTIONAL

Table 1: Optical Bench specification table.

Off-Axis Parabolas (OAPMs)

Two off-axis parabolic mirrors are requested. They are mounted in custom optomechanics based on gimbals to set their tip/tilt angle. They are optically identical, but mounted symmetrically in the optomechanics, to respect the scheme of Figure 2. When installed on the bench, the center of the two OAPMs and the center of the two FMs shall have the same height as respect the optical bench, as shown in Figure 3. The optical prescriptions are reported hereafter, along with the prescriptions for the optomechanics. The optical quality shall be guaranteed when the mirror is installed on its mechanical support on the optical bench. Evidence of this shall be provided by the contractor. Provision to install mechanical references to align the mirror on the optical bench will be discussed between the contractor and INAF.

All optical and mechanical surfaces should be cleanable. It is mandatory for external optical surfaces. At delivery, the cleanliness level shall be compatible with Class 10000/ISO7. The shipping conditions as well as the final product must comply with this requirement. The transport units shall be designed to be opened in cleanroom conditions as well as preventing damage to the optics.

The OAPMs into their optomechanics should foresee threaded interfaces to safely lift the whole assembly.

Req. #	Type	Value	Comment
OAPM-1	Mirror material	ZERODUR™ or equivalent	Low thermal expansion glass
OAPM-2	Mirror shape	Round	
OAPM-3	Mirror mechanical diameter	500 mm ± 0.5mm	
OAPM-4	Mirror clear aperture, CA	> 450 mm	
OAPM-5	Mirror edge thickness	-	Sufficient to guarantee the requested surface quality
OAPM-6	Mirror focal length	6000 mm ± 1%	
OAPM-7	Mirror off-axis distance	704 ± 1mm	Equivalent off-axis angle of 6.716°
OAPM-8	Mirror surface accuracy on CA	≤ 30 nm RMS	When mounted in the optomechanics
OAPM-9	Mirror surface quality	40/20	
OAPM-10	Mirror coating	Protected metal coating	
OAPM-11	Mirror reflectivity	>88% (630 – 640 nm)	
OAPM-12	Mirror axis height vs. optical bench	Same as for FMs	When optics are mounted in the optomechanics
OAPM-13	Mirror axis height tolerance vs. optical bench	± 1mm	When optics are mounted in optomechanics
OAPM-14	Tip/tilt range	> 1°	

OAPM-15	Tip/tilt resolution	< 5 arcsec	
OAPM-16	Total width	< 770 mm	This is the maximum width of the optical element mounted in the mechanics
OAPM-17	Total thickness	< 300 mm	This is the maximum thickness of the optical element mounted in the mechanics
OAPM-18	Interface optomechanics – Optical table	The thickness of this interface will bring the center of the OAPMs to the height of the center of the FMs.	OPTIONAL In agreement with OAPM-13 and FM-11 and considering the footprint FM-16.
OAPM-19	Optical reference for alignment	Steel spheres, corner cube …	OPTIONAL
Note: the optical requirements for the mirrors shall be evaluated at a temperature between 20°C and 22°C. The temperature shall be specified in the technical documentation.			

Table 2: Off-Axis Parabola Mirror specification table.

Flat Mirrors (FMs)

Two flat mirrors are requested, optically identical. They are mounted in a custom optomechanics based on gimbals to set their tip/tilt angle, and the optomechanics mounted on a motorized rotating stage to set the angle along the vertical axis. When installed on the bench, the center of the two FMs shall have the same height as the axis of the OAPMs as respect to the optical bench, as shown in Figure 3. This shall account for the optomechanical mounting on the rotating stage. The optical prescriptions are reported hereafter, along with the prescriptions of the optomechanics. The optical quality shall be guaranteed when the mirror is installed on its mechanical support on the optical bench. Evidence of this shall be provided by the contractor.

All optical and mechanical surfaces should be cleanable. The cleaning process must be provided. At delivery, the cleanliness level shall be compatible with Class 10000/ISO7. The shipping conditions as well as the final product must comply with this requirement. The transport units shall be designed to be opened in cleanroom conditions as well as preventing damage to the optics.

The FMs into their optomechanics should foresee threaded interfaces to safely lift the whole assembly.

Req. #	**Type**	**Value**	**Comment**
FM-1	Mirror material	ZERODUR™ or equivalent.	Low thermal expansion glass
FM-2	Mirror shape	Circular	
FM-3	Mirror mechanical Diameter	600 mm ± 0.5mm	
FM-4	Mirror clear aperture, CA	>550 mm	
FM-5	Mirror edge thickness		Sufficient to guarantee the requested surface quality
FM-6	Mirror surface accuracy on CA	≤ 20 nm RMS	When mounted in the optomechanics
FM-7	Mirror surface quality	40/20	
FM-8	Mirror coating	Protected metal coating	
FM-9	Mirror reflectivity	>88% (630 – 640 nm)	For Angle of incidence from 0° to 40°
FM-10	Mirror center position vs. optical bench	Same as for OAPMs	When optics are mounted in the optomechanics
FM-11	Mirror center position tolerance vs. optical bench	± 1mm	When optics are mounted in the optomechanics
FM-12	Gimbal tip/tilt range	>1°	
FM-13	Gimbal resolution	< 1.4 mdeg	
FM-14	Total width	< 880 mm	This is the maximum width of the optical element mounted in the mechanics
FM-15	Thickness	< 300 mm	This is the maximum thickness of the optical element mounted in the mechanics
FM-16	Interface optomechanics – rotary stage	Mechanical element to connect the two components defining the center of rotation.	OPTIONAL
Note: the optical requirements for the mirrors shall be evaluated at a temperature between 20°C and 22°C. The temperature shall be specified in the technical documentation.			

Table 3: Flat Mirror specification table.

Motorized Rotary stages for FM

Two rotary stages, one for each FM, must be mounted below the flat mirror assembly and they define the angle of incidence of the collimated beam coming from the OAPM.

The rotary stage is considered to include every component for its operation, such as drivers, appropriately sized cables, controller.

A proper interface should be present to link them to the FM optomechanics.

Req. #	Type	Value	Comment
RS-1	Rotary stage material	monolithic stainless steel design	
RS-2	Rotary stage centered load capacity	≥ 3500N	
RS-3	Rotary stage accuracy garanteed	≤ 3.5 mdeg	
RS-4	Rotary stage resolution – minimal incremental motion	≤ 0.3 mdeg	
RS-5	Wobble	< 0.5 mdeg	
RS-6	Rotary stage software	Labview drivers	
RS-7	Rotary stage cable length	≥ 5 m	Cable from stage to controller
RS-8	Interface optomechanics – rotary stage	Same of FM-16	OPTIONAL
RS-9	Suitability of the decentralized Load	The off-center load generated by FMs mounted in their mechanics must be compatible with the off-center load limit of the proposed rotary stage	

Table 4: Rotary Stage for FMs specification table.

Motorized Rotary stages for sample

A metal holder of dimensions approximately 700mm (X: coordinate parallel to the optical table) x 600mm (Y: coordinate perpendicular to the optical table) x thickness 100mm, will be moved of the high-precision rotating slides along the axis passing from the center of the X coordinate and parallel to the Y coordinate. The principal function of the holder will be to support a glass plate during holographic writing phase.

The load is slightly off-center because the axis of rotation will lie on a largest face of the glass plate. The rotary stage is considered to include every component for its operation, such as drivers, appropriately sized cables, controller.

Req. #	**Type**	**Value**	**Comment**
RS1-1	Rotary stage material	monolithic stainless-steel design	
RS1-2	Rotary stage load capacity	≥ 1200N	
RS1-3	Rotary stage accuracy	≤ 3.5 mdeg	
RS1-4	Rotary stage resolution	≤ 0.3 mdeg	
RS1-6	Rotary stage software	Labview drivers	
RS1-7	Rotary stage cable length	≥ 5 m Cable from stage to controller	

Table 5: Rotary Stage for Sample specification table.

There is also an optional rotary stage for the sample that should be used in specific working cases to increase the production flexibility. Such stage shows lower accuracy and resolution. The controller can control both this stage and the previous mandatory one.

Req. #	**Type**	**Value**	**Comment**
RS2-1	Rotary stage material	monolithic stainless-steel design	OPTIONAL
RS2-2	Rotary stage load capacity	≥ 1200N	
RS2-3	Rotary stage accuracy	≤ 20.0 mdeg	
RS2-4	Rotary stage resolution	≤ 3.5 mdeg	
RS2-6	Rotary stage software	Labview drivers	
RS2-7	Rotary stage cable length	≥ 5 m Cable from stage to controller	

Table 6: Rotary Stage for Sample specification table.

Laser

The laser source is crucial for the holographic setup and must have stability and long coherence. The wavelength should be in the red because the holographic materials show less scattering in this spectral region. Another important parameter is the power because large collimated beams are generated by the OAPMs and the irradiance must be large enough to write the holographic setup in a short exposure time.

We require continuous high-power single-red-line-emitting laser, possibly remoted via driver/software, with an all-fiber modular internal architecture (in which possibly only the emitting head can be placed on the optical bench, and the rest of the body far away) and output beam in the air.

The laser should not involve lengthy calibration and stabilization sessions, thus presenting itself as "plug-and-play" device as possible.

Req. #	Type	Value	Comment
L-1	Mode of operation	Constant power	
L-2	Type	Continuous Wave (CW), free space	
L-3	Spatial Mode	Single mode, TEM00	
L-4	Wavelength	630 – 640 nm	
L-5	Linewidth	≤ 250 kHz	
L-6	M^2 beam quality	≤ 1.2	
L-7	Beam diameter	1 – 2 mm	
L-8	Power	≥ 2 W	
L-9	Power Beam Stability over 8h	≤3.0%	
L-10	Interstage pickoff	> 5 mW @ 1064 nm	As side emission for inline monitoring
L-11	Air Cooling	Static thermal dissipating system	
L-12	Laser Remote Control	Through PC interface and software	Labview preferred
L-13	Distance emitting head - controller	>1.1m	

Table 7: Laser specification table.

4 Graphs and Drawings

The drawings of the optical bench with the range of the dimensions are reported here.

The number of legs, their position and geometry are given for illustration purposes. The supplier will propose his optimal solution given the load areas shown in the table.

The technical junction shown in the figure 4 are for illustrative purposes. The number of technical junction may vary in number and geometry depending on the supplier's optimal proposal, remembering that the largest dimension of any single table cannot exceed 4000mm (Req. OB10).

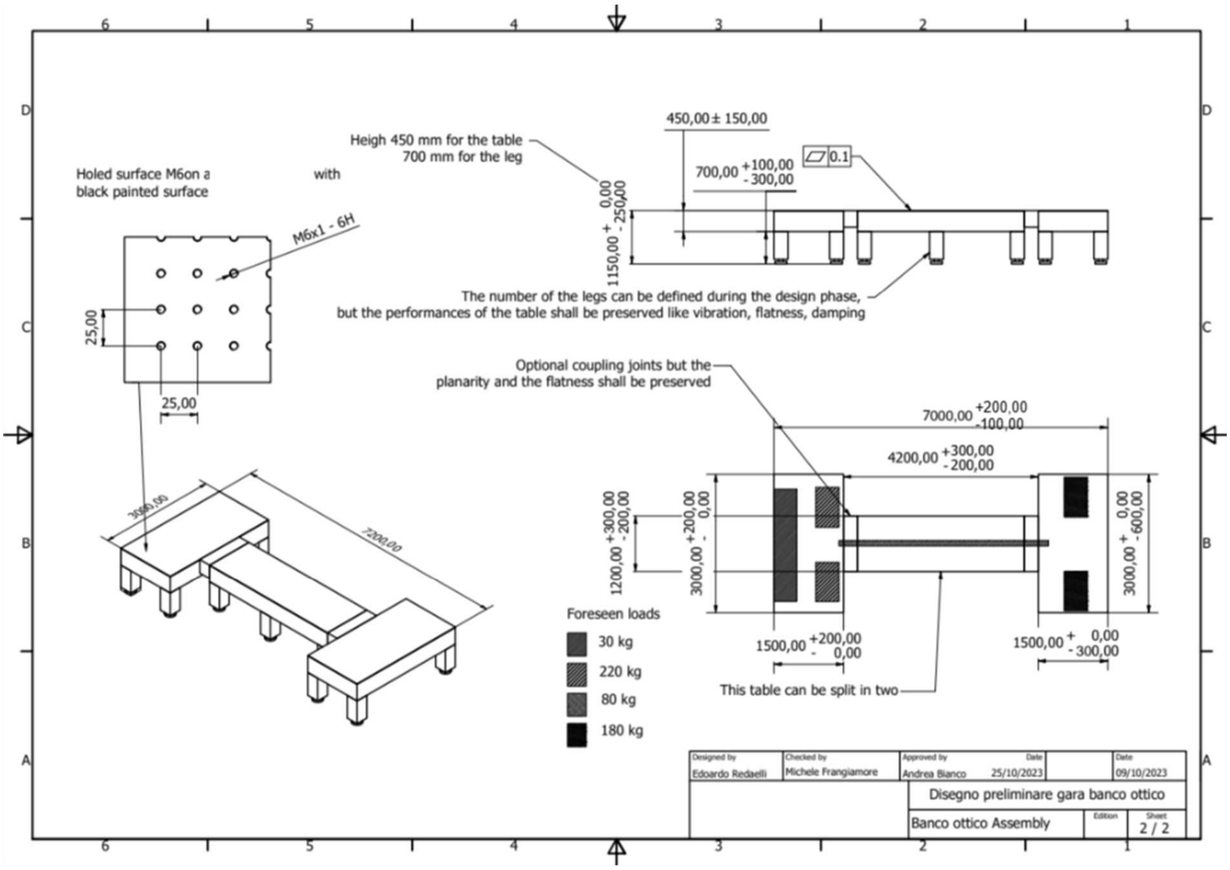

Figure 4: Scheme of the optical table with quotes and some details.

The figure 5 show the geometric layout and axonometry of the assembled optical setup with the major volumes; the cylinders represent the mirrors and consequently the blue lines represent the light paths. The floating-elevated plane behind the two major cylinders (FMs), circumscribes the region where beam folding and reformatting optics will be placed, as well as the laser head.

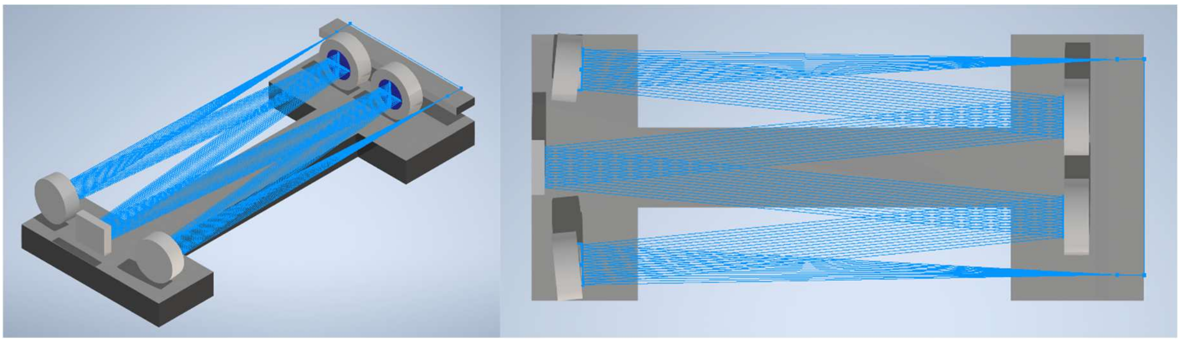

Figure 5: Scheme of the holographic optical setup assembled with optical table geometry - version with converging beams far

In figure 6, we show how a mechanical support is arranged to move along the major axis of the "H-shaped" table, the footprint of this mechanical is represented by a square-based parallelepiped that is now very close to the FMs, while in the previous view it was near the OAPMs.

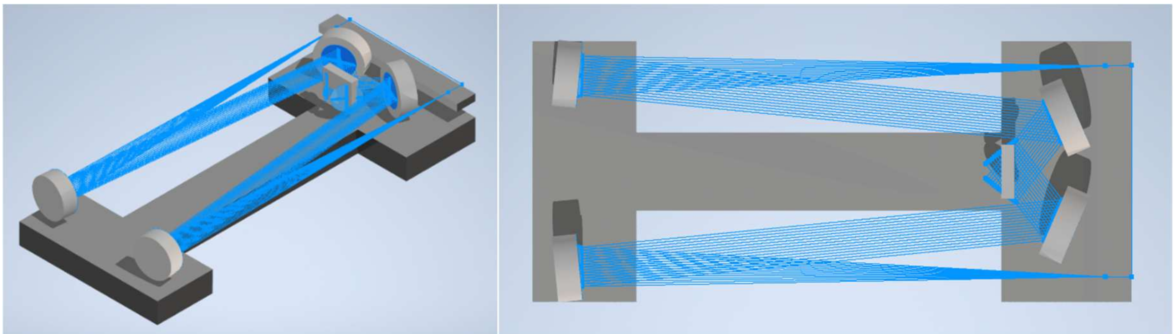

Figure 6: Scheme of the holographic optical setup assembled with optical table geometry - version with converging beams near

Finally, the rendering in figure 7 illustates the final setup in the laboratory. One can recognize the FMs in the foreground on the table and, on the opposite side, at the far end of the room, the OAPMs; finally on the raised bench, on the back of the FMs in the foreground, the laser head (left side of the raised bench) and the various folding and reformatting optics of the laser beam. The drawing shows a modular laser in which the beam-emitting head (and eventually other cold components) is aligned with the optical system above the bench, while via a fiber-optic system the hot components of the laser are carried at a distance, such as to the foot of the table.

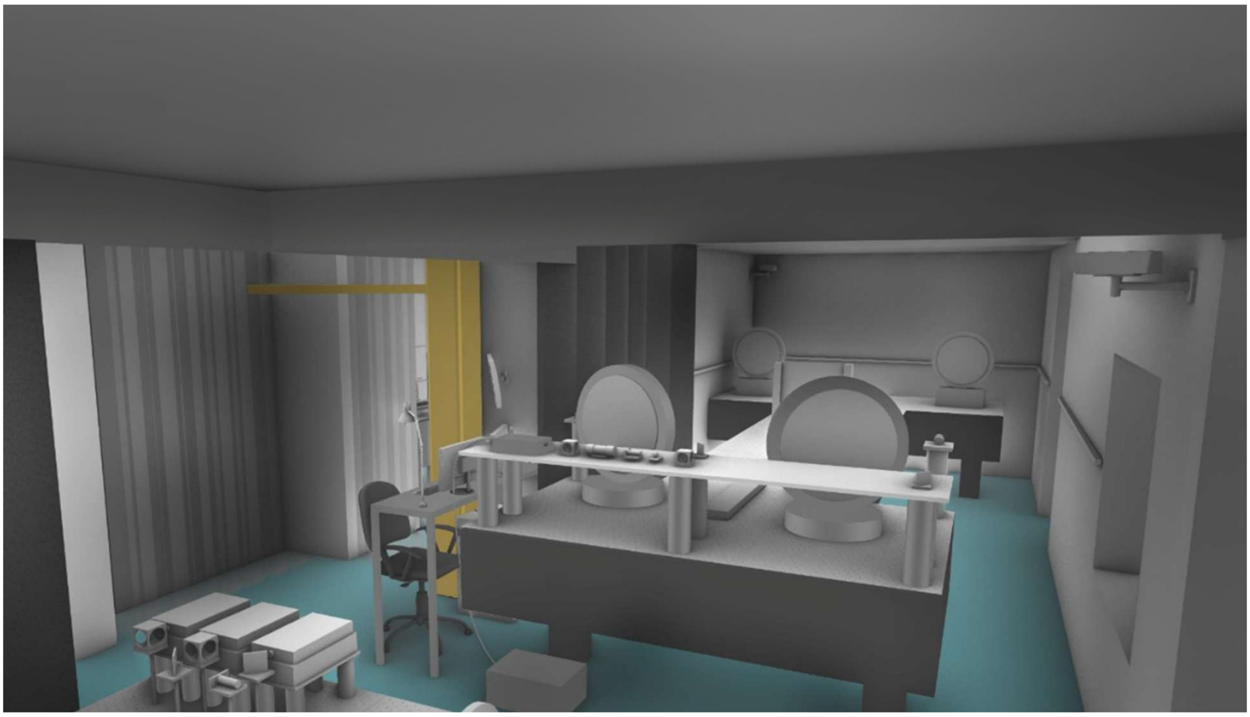

Figure 7: Scheme of the holographic laboratory with hypothetical environment.