

## Measurement Automation Implemented in the Laser Station «Tochka»

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*Operating modes of the SLR-station «Tochka» designed for precision laser ranging and taking ephemeris-time measurements in the GLONASS system have been analyzed. Technical solutions enabling the station to automatically capture and track targets during both day and night observations have been considered.*

*An algorithm of the station functioning in ranging mode which automatically sets the single-electron mode of return pulse reception, controls parameters of the laser emitter and configures the optomechanical path is presented. Also, technical solutions enabling automatic calibration of range measurements in relation to the station's reference point have been covered.*

### Introduction

The laser station «Tochka» is designed for precision ranging to geodetic and navigation spacecraft equipped with laser retroreflector systems, precision time transfer through spacecraft «Glonass» equipped with laser pulse reception modules and for pseudorangeing by code and phase of the carrier frequency of GLONASS and GPS navigation signals.

Taking into consideration that the measurement data volume required to perform all observation tasks is huge [1], station «Tochka» is designed with reference to the necessity of operation at high performance rates and with a high level of measurement automation.

### «Tochka» operating modes

The laser station «Tochka» can function in one of the following modes:

- fully automatic measuring mode, in accordance with the work plan received from ballistics centers or previously generated by the station operators;
- semi-automatic measuring mode, in accordance with the work plan being promptly corrected by the station operators;
- manual mode, with tracked objects and tracking modes selected directly by the station operators.

The diagram of «Tochka» operating modes is given on Figure 1.

In PREPARATION mode, the laser station and its control system which includes 8 computers provide generation of the work plan, calculation of target designations, equipment switch-on and warm-up, dome shutter opening, release (braking-off) of pan-tilt device mechanisms and initialization of the digital electric power drive.

Once the laser station's equipment has been switched on and warmed up, DIAGNOSTICS mode is initialized immediately and then being continuously executed. Key procedures of DIAGNOSTICS mode are equipment health and station's work program execution monitoring.

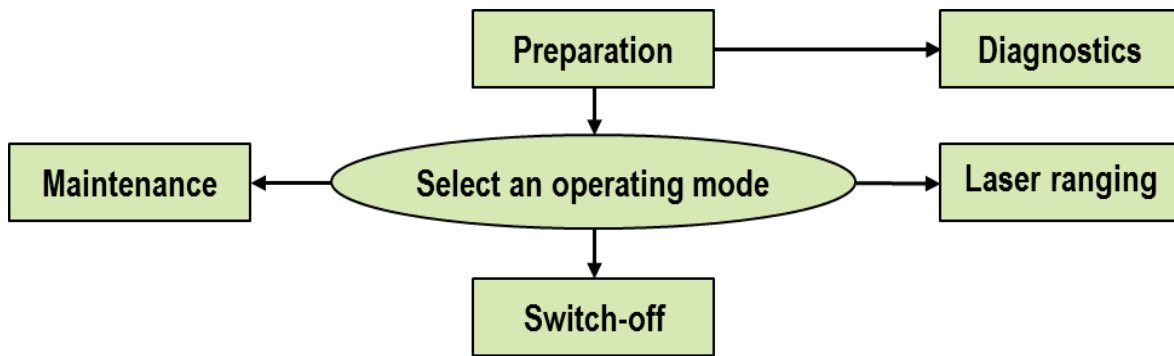


Fig. 1 Diagram of «Tochka» operating modes

MAINTENANCE mode is introduced to the work program and executed quarterly or less frequently in semi-automatic mode involving an operator in order to check functioning quality of the station and performance accuracy of its key subsystems.

If DIAGNOSTICS mode has been successfully executed, LASER RANGING mode is initialized and then takes measurements in fully automatic, semi-automatic or manual control modes.

Generally, the station software is aimed at taking measurements in fully automatic mode which is considered to be the main operating mode. To achieve this, the station software is supported and provided by performance automation of the station's key subsystems: laser beam pointing system, ranging system and measurement calibration system.

### Laser station's control system

Station's operating modes are controlled by the control system including 8 computers controlling various subsystems and a set of control units which open and close dome shutters, control power supply, weather station, air conditioning, electromechanical process execution modules and etc.

The functional diagram of the control system is illustrated on Figure 2.

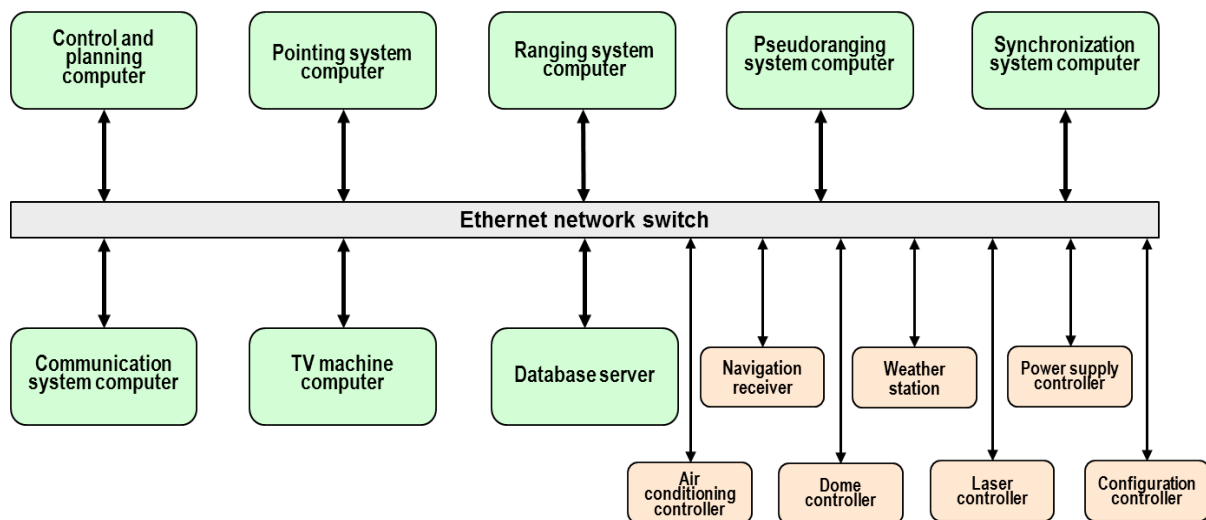


Fig. 2 Functional diagram of the control system

Data transmit/receive computer provides reception of external information including requests for measurement taking, ephemerides in CPF format and special data on observed SC, Earth's rotation parameters, data on restrictions to measurement taking.

Data transmit/receive computer also provides transmission of measurement information including data on ranging and pseudoranging in CRD format, as well as code and phase measurements of the GLONASS, GPS and Galileo navigation signal receiver in RINEX format.

Input and output information is stored on the database server containing ballistic support database tables and file storage for measurement results.

Control and planning computer performs preparatory operations for station's switch-on, evaluates station health monitoring results and, using data from the database server, generates work schedule for the station and target designation files.

Pointing system and TV machine computers together provide target capture and tracking in automatic mode. Feedback to the pointing system computer is provided by the ranging system one which processes return pulse reception event streams.

For station performance automation, an important role is played by the laser beam pointing and return pulse detection/processing algorithms.

### Laser beam pointing system automation

Pointing system performance automation means execution of the laser beam pointing procedure under both night and day conditions without involving an operator in «blind» mode, i.e. having no data on a target's angular position in relation to the station's optical axis.

In the laser station «Tochka», automatic «blind» pointing under night and day conditions is performed in accordance with the pointing diagram illustrated on Figure 3:

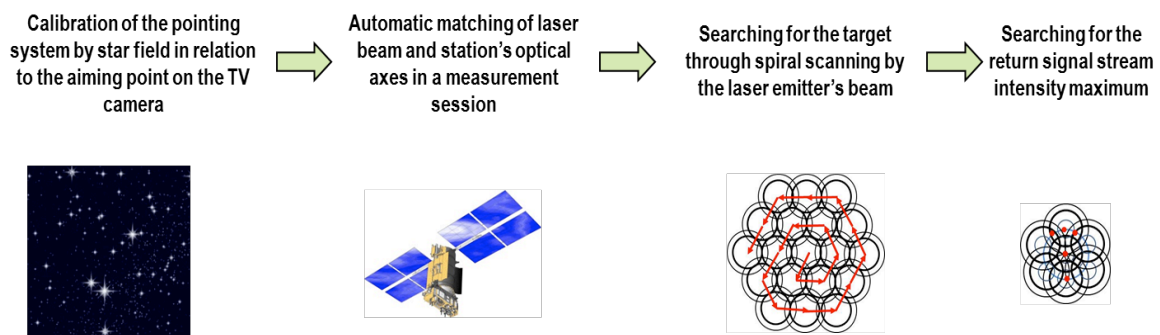


Fig. 3 «Tochka» pointing execution diagram

At the first stage, calibration of the pointing system by star field is performed and corrections for control signals by azimuth and elevation are calculated. This procedure is executed on a regular basis, moreover, there is a mode of pre-session calibration improvement by a few day or night stars being in close proximity to the target's path. Calibration is performed in relation to the aiming point on the TV CCD-camera.

At the second stage, when a session is in progress, the station launches the system which automatically locks the laser beam marker close to the aiming point, continuously matches laser beam and station's optical axes and uses the hollow truncated prism to transfer the direction of a transmitting laser beam.

At the third stage, if return laser pulses have not been detected within a set period of time, the station initializes search for the target through spiral scanning by the laser emitter's beam. Scanning area is set in the range of 0.5 to 1 arcmin.

At the fourth stage, once the target has been captured, there is a mode of search for return signal stream intensity maximum which is launched on condition that signal photoelectron arrival frequency is less than 5 Hz.

Extremum is found through scanning the target's vicinity with a small step and rising a position with the most signal stream intensity.

Generally, pointing system algorithm automation is aimed at automatic target capture within the period of time not exceeding 1.5-2 minutes, considering the time spent on receiving telescope repointing at the next object for tracking.

### Ranging system automation

Once the laser beam has been pointed and return laser pulses have been received, in order to achieve high accuracy of ranging the station must automatically keep up the return pulse intensity at the single-electron level.

Speaking of the laser station «Tochka», this task is completed by the ranging system which measures the frequency at which signal and background streams arrive at the event timer output and automatically controls the attenuator installed inside the receiving optical path.

Besides of that, the ranging system automatically controls laser emitter launch frequency to avoid collisions, sets the laser emitter beam width and receiving channel FOV, sets the narrow-band filter of the day channel upon exceeding the set background level and controls laser beam scanning.

Generally, ranging system automation is achieved through introduction of electromechanical process execution modules controlled using the local network to the station, as well as through interaction of the ranging program with control, planning, ballistic support and pointing ones. The diagram showing interaction between the ranging and control systems is presented on Figure 4.

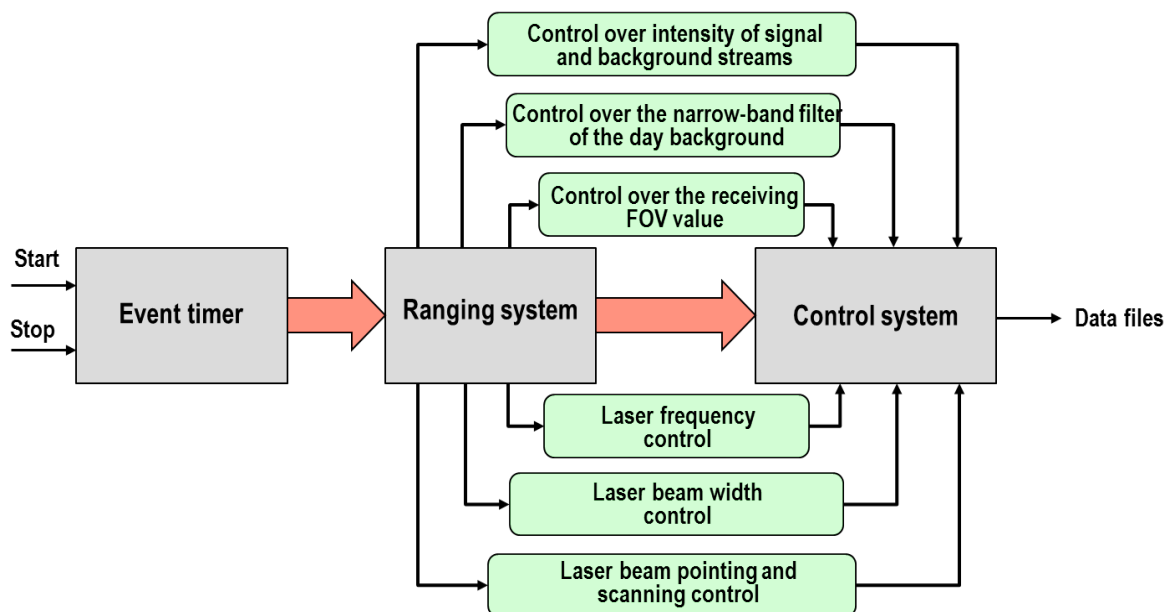
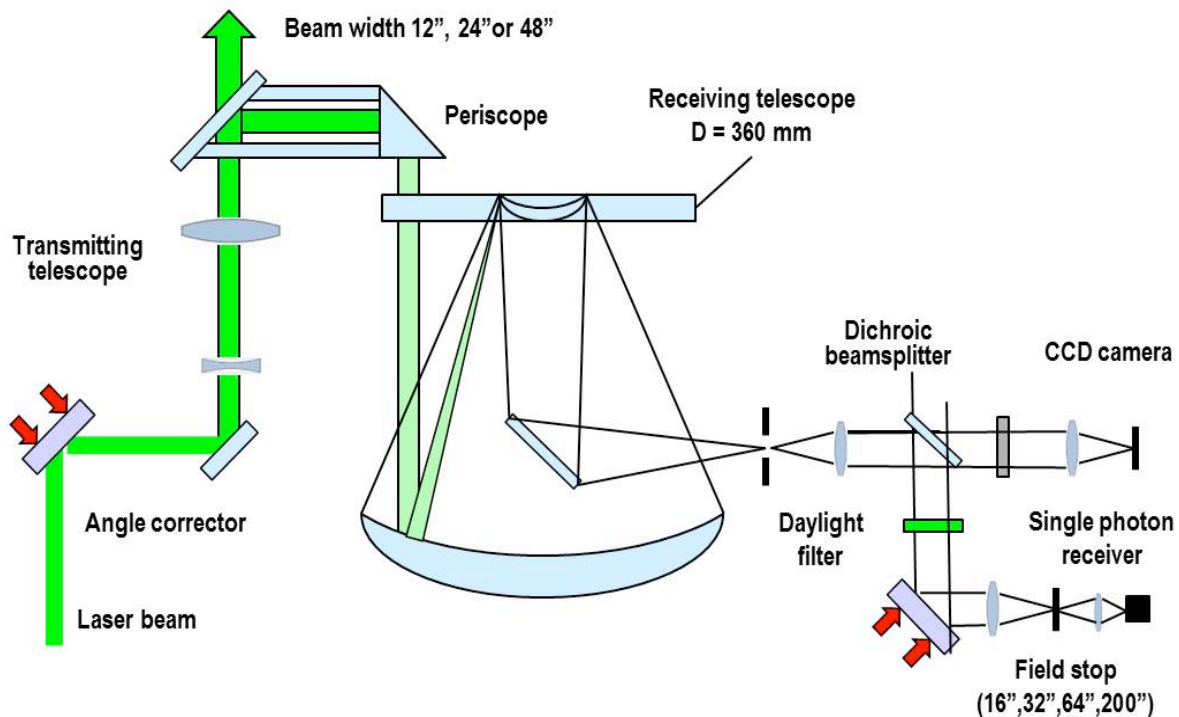


Fig. 4 Diagram showing interaction between the ranging and control systems

## Ranging calibration automation

One of the steps to achieve high accuracy of measurements is the equipment calibration procedure (current hardware correction determination) which must also be automated.

The laser station «Tochka» is calibrated using the standard distance of about 1m in length installed inside the receiving telescope in accordance with the diagram illustrated on Figure 5.



*Fig. 5 Ranging system's automatic calibration diagram*

In the end of the standard distance there is a hollow prism redirecting the laser pulse stream to the receiving channel.

So, calibration measurements are taken automatically and simultaneously with distance measurements within each session. The distance in relation to the station's reference point is determined as a difference between distance and calibration measurements, considering the known standard distance length.

At the present moment, the given key technical solutions have a sufficient level of approval and provide tracking in automatic mode.

Nevertheless, the task of complete automation is multi-parameter and at the stage of operation will require improvement and optimization of software configuration parameters including selection of tracking strategy and priorities.

## Conclusion

Technical solutions and software of the laser station «Tochka» provide an opportunity to perform tracking in automatic mode under both night and day conditions.

Implementation of an automatic tracking mode at the stage of operation will require improvement and optimization of software configuration parameters including selection of tracking strategy and priorities.

#### **REFERENCES**

- [1] M. Sadovnikov, V. Shargorodskiy: «Methods for coordinate and time data collection in the laser station «Tochka» // 20<sup>th</sup> International Workshop on Laser Ranging, Potsdam, Germany, 2016.