Shanghai Astronomical Observatory
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Establishment and Observation of Space Debris Laser Ranging

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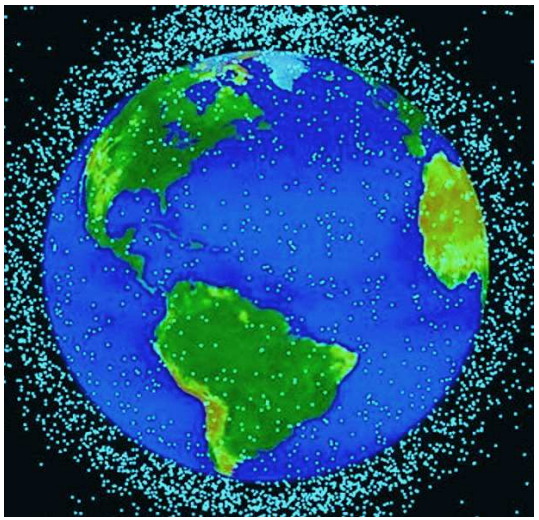
Introduction

- Large amount of space debris around the earth currently.
- Increasing the probability of collision accident between the space targets.
- Become a major problem for nations which are active in space.
- Need kinds of methods for high precise measurement and accurate catalogue for space debris to protect against debris collision.



Introduction

- China, one of the members of the IADC (Inter-Agency Space Debris Coordination Committee) has paid great attention to reduce possible damage from space debris.
- Laser ranging (LR) is a kind of real-time measuring technology with meter or sub-meter precision for space-debris observation.
- With the support of National Projects, Shanghai Observatory firstly in China began to research on the LR technology to space debris from 2006.

Establishment of laser ranging to space debris system

- **Key techniques were investigated and modifications implemented based on the 60cm SLR system at Shanghai Observatory in 2006-2008.**


SLR House in Shanghai


60cm SLR telescope

Establishment of laser ranging to space debris system

Modifications:

- 40W laser ;
- Rebuilding the laser coude system and transmitting telescope ;
- Improvement of photon detector, control system, tracking system etc.

Preliminary laser ranging system was constructed in 2008.

40W Laser

Performance:

Frequency：20Hz ，

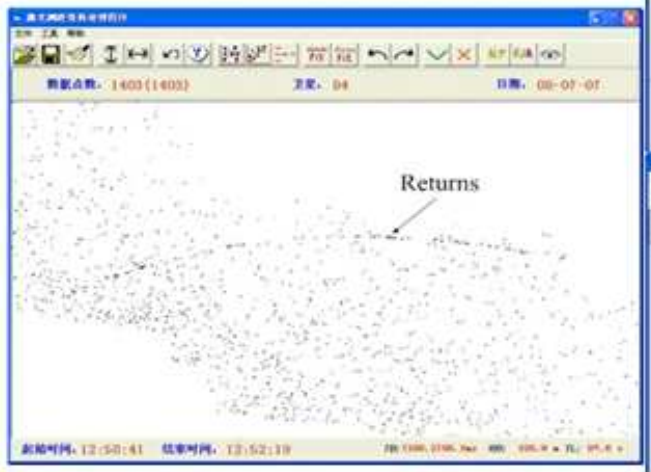
Energy： 2J ，

Pulse width：10ns

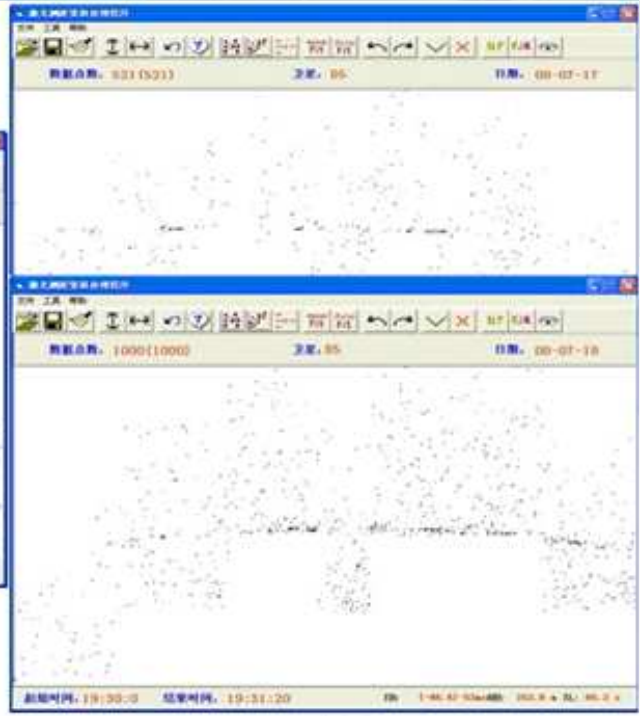
Preliminary Results

(a) The discarded Soviet rocket (ID: 17912) on July, 2008;

(b) The discarded US rocket (ID: 30778) on July 17/18, 2008

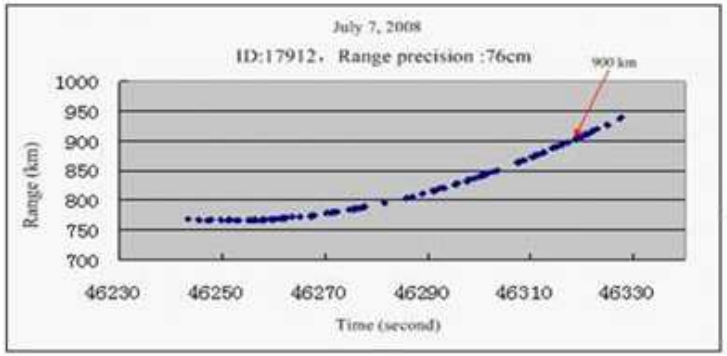


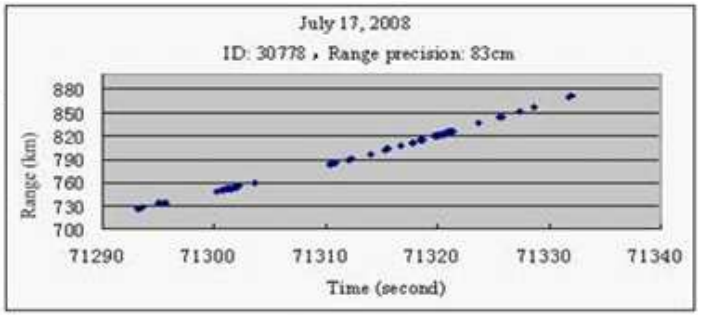
(a)

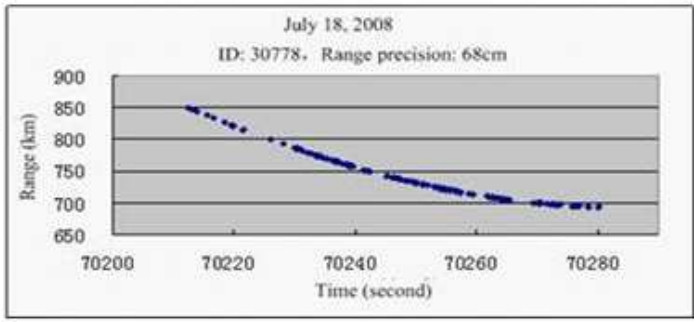


(b)

The range variations for each pass







The maximum range obtained in the measurement was 936 km.

Establishment of laser ranging to space debris system

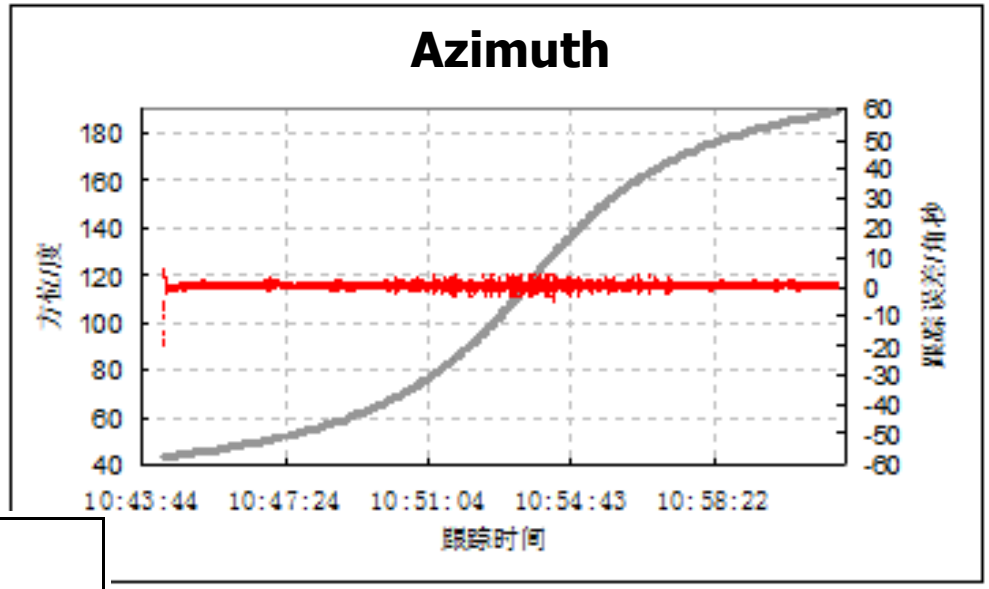
For further studying laser ranging to space debris technology, we have been upgrading our laser measuring system in 2009-2010, including:

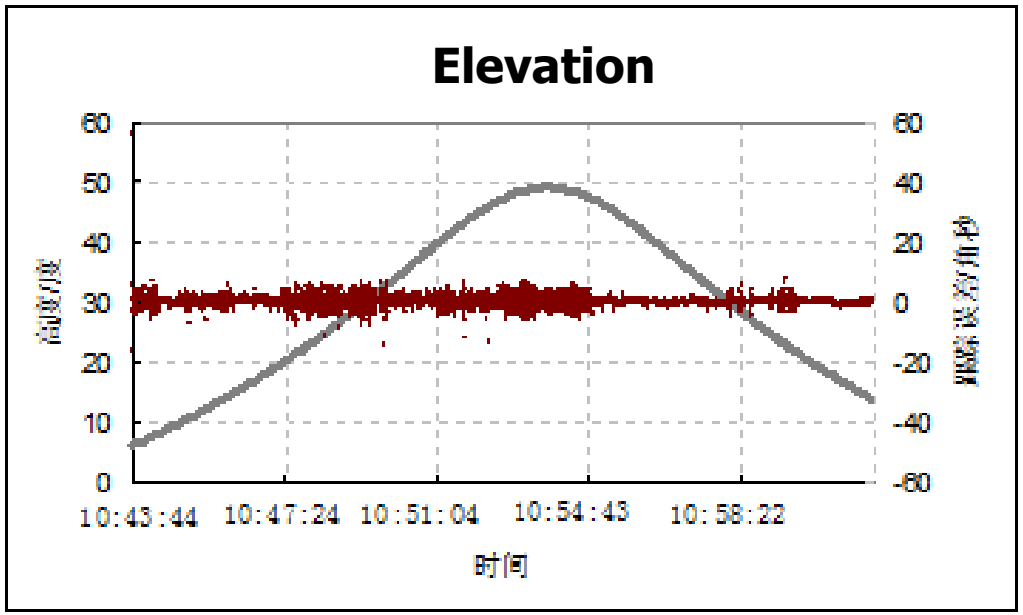
- **adopting stable high power laser**
- **improving the capability of servo-tracking system**
- **Multi step range gate adjusting automatically**
- **adopting Two Line Elements (TLE) predict orbit , its precision <1km**

Performances of stable high power Laser

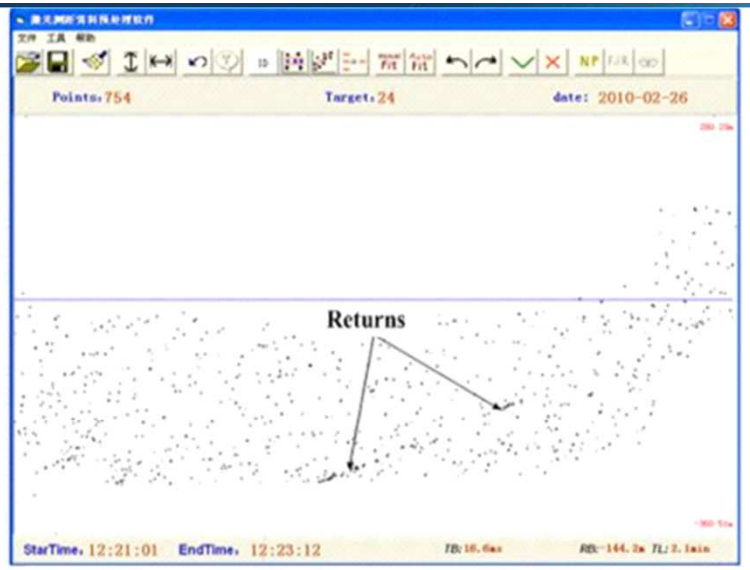
- Repetition rate: 10Hz Energy: 1J per shot
- Diverge: 0.5mrad Pulse width: 8ns
- Wavelength: 532nm Laser diameter: 13mm
- Continuous working time >1hour

Improvement of tracking capability

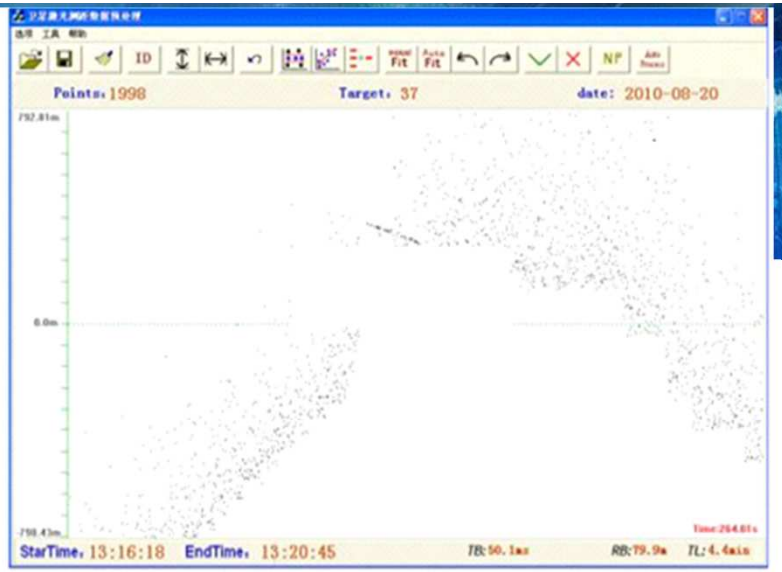




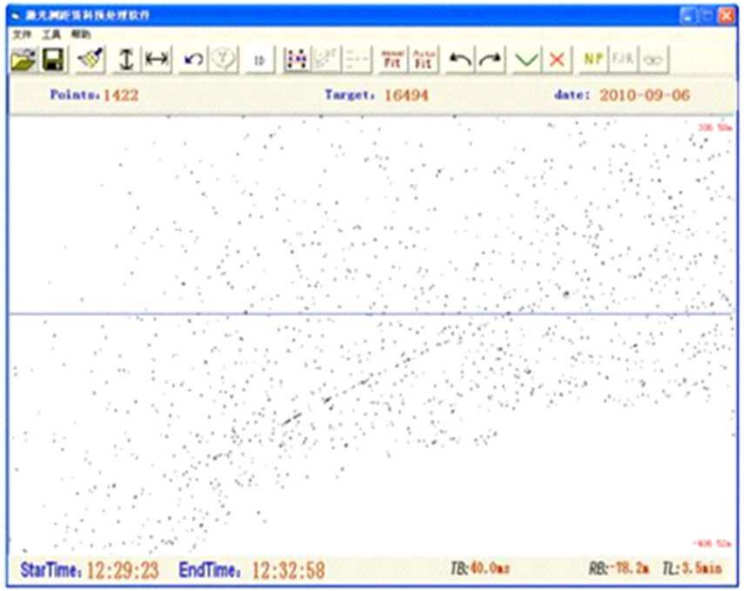
Tracking RMS is less than 2”



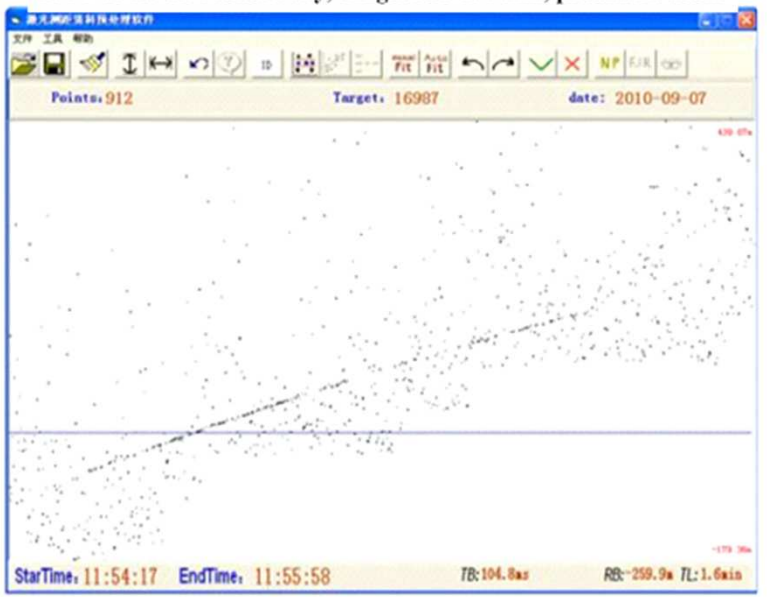
2010-03-26 Iridium satellite, range: 750-800km, precision: 60cm



2010-08-20 US rocket body, range: 950-1010km, precision: 65cm



2010-09-06 Russia rocket body, range: 1100-1200km, precision: 80cm



2010-09-07 Russia rocket body, range: 840-1100km, precision: 58cm

Some of the measuring results from the 10W laser in 2010

Successfully measuring passes is low (<20%)

Establishment of laser ranging to space debris system

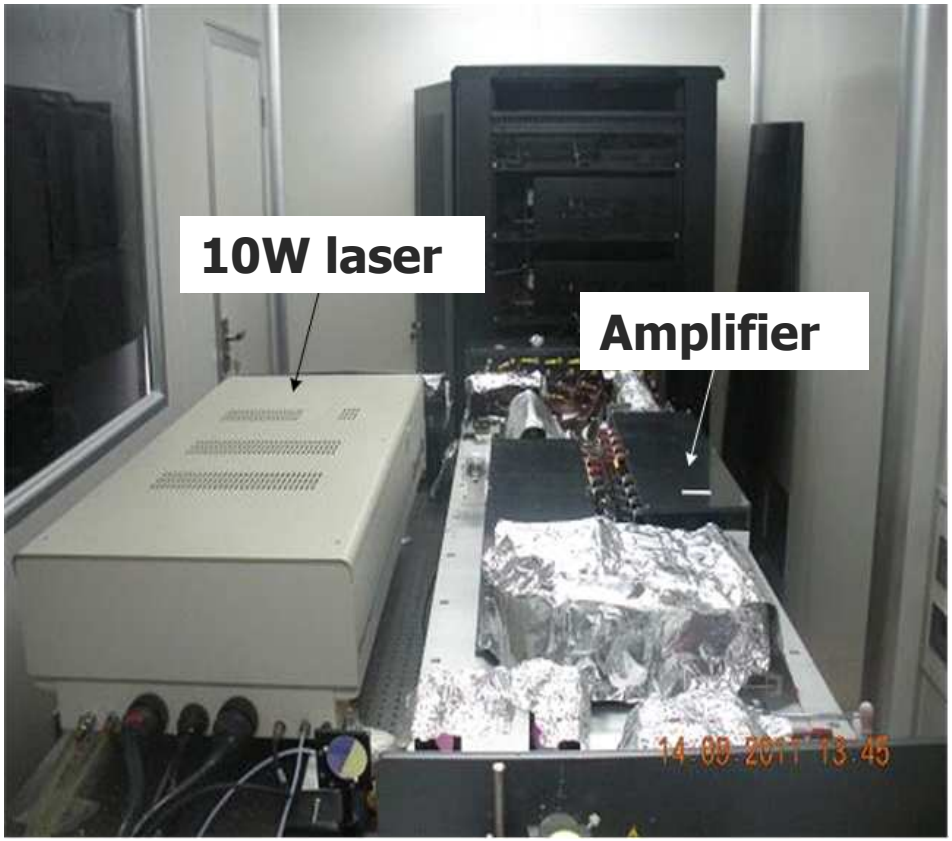
Based on the 10W laser observation system, the following modifications have been done to further increase the ability of laser tracking for space debris in 2011:

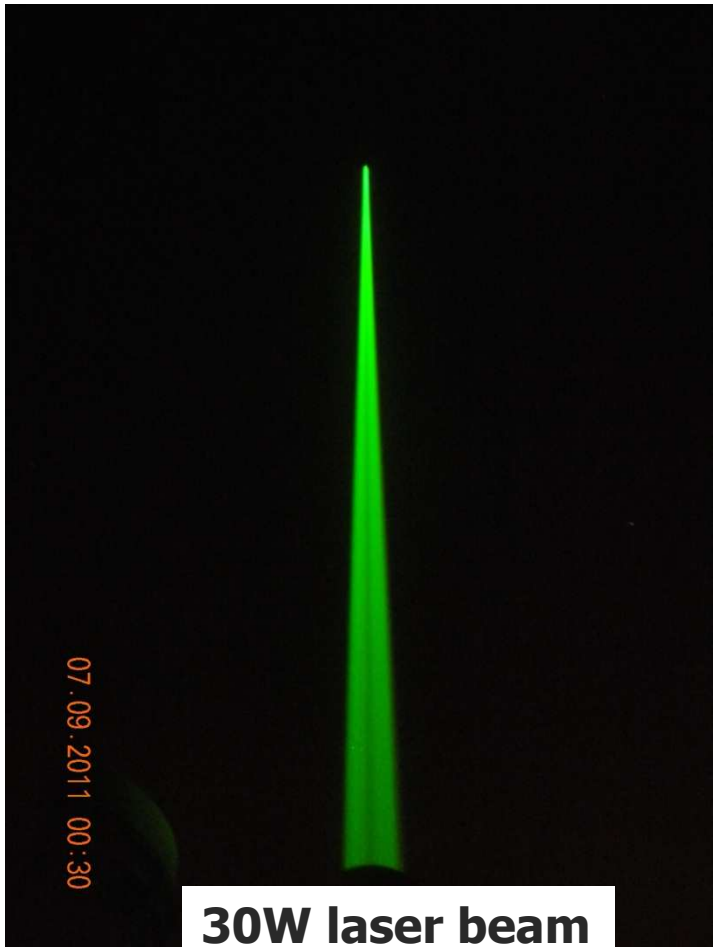
- **Laser power enlarging**
- **Automation improving**
  - ➢CCD closed tracking
  - ➢Calculation of Laser beam point for adjustment automatically

Laser power enlarging

- **Adapting 10W Laser**
  - Fundamental laser (1064nm) as input of amplifier.
  - Four-stage amplifier
- **Performances:**
  - Power : 30-35W
  - Divergence: 15”
  - Wavelength: 532nm
  - Repetition rate: 10Hz

Laser power enlarging



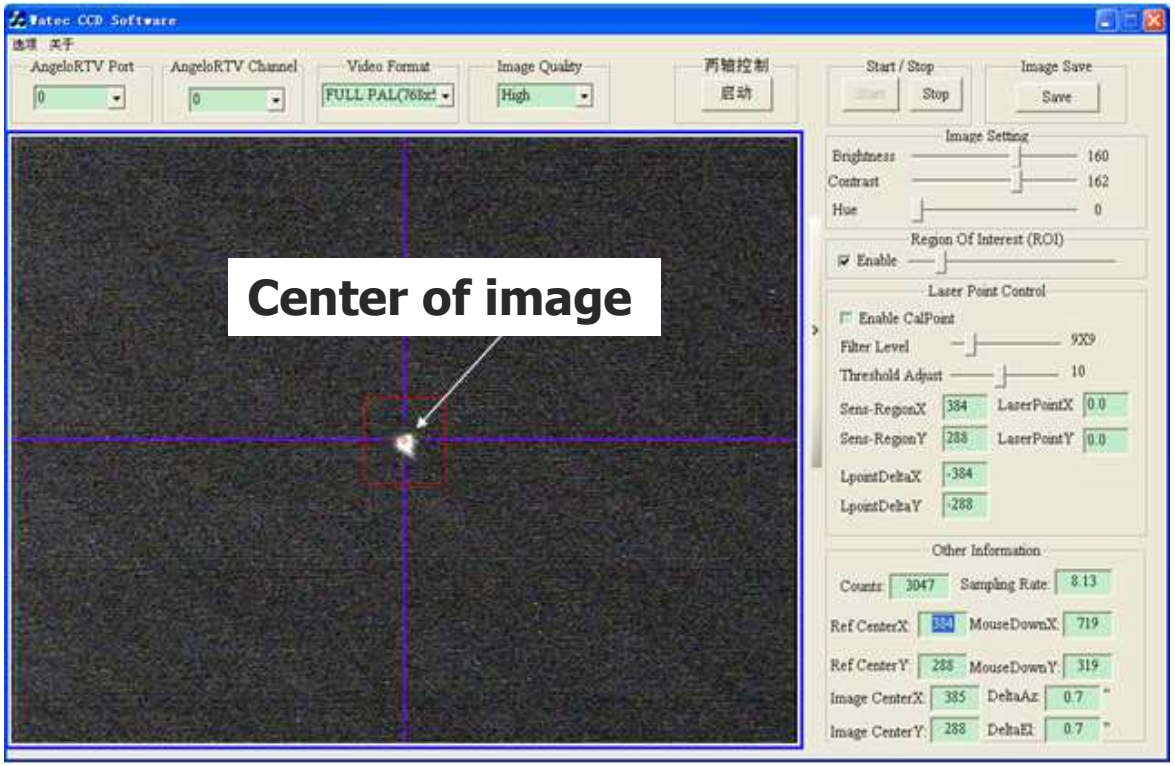


Automation improving

- **Large time bias and range bias for prediction of space debris target.**
- **The during time of passes for space debris (LEO) through the station is short (less than 6 min).**
- **Automation will improve the efficiency of search greatly.**
  - **CCD closed tracking**
  - **calculation of laser beam point for adjustment automatically**

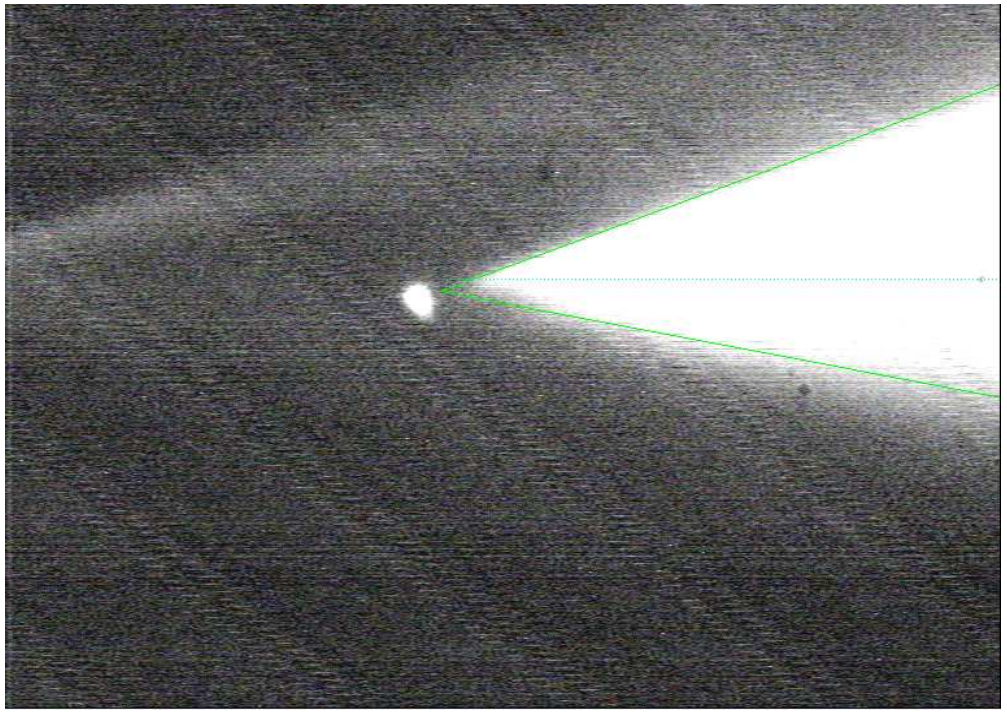
CCD closed tracking

- Calculating the centre of target image.
- Getting the offset between the centre and Reference position.
- Sending the offset value to tracking control software.
- Tracking RMS is less than 2″

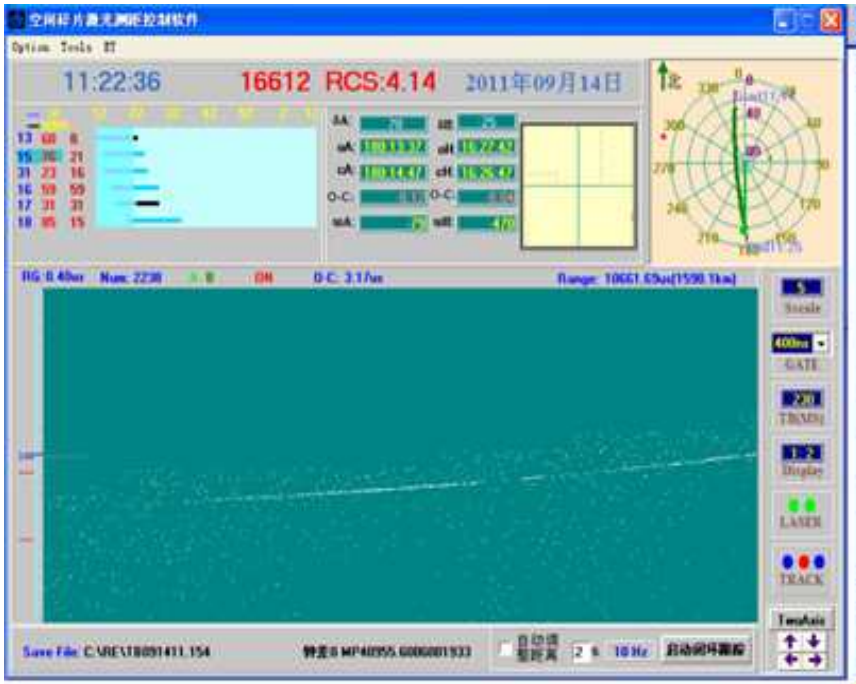


Calculation of laser beam point

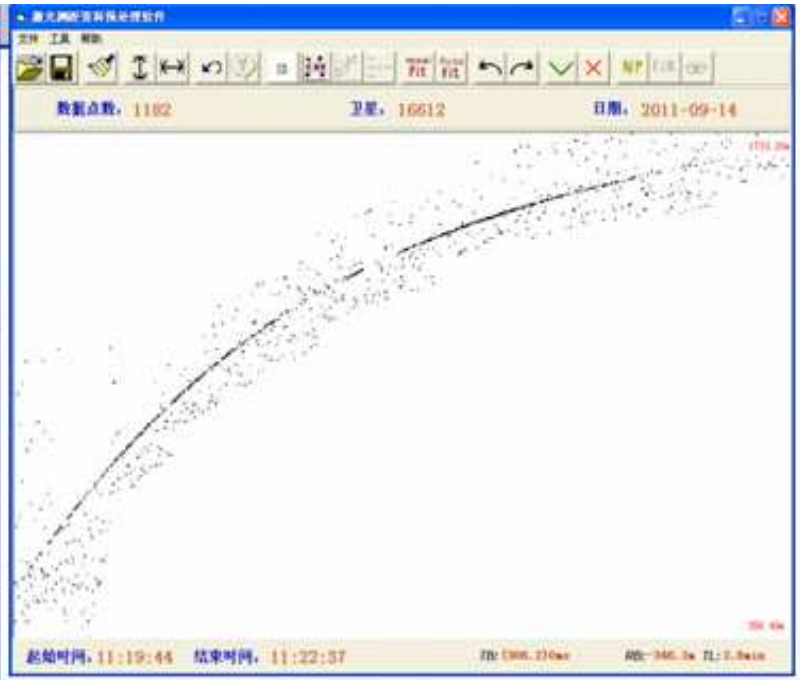
- **Dividing the image of laser beam into two parts by the line, top borderline and bottom borderline.**
- **Least square fitting all pixels of the borderline.**
- **The intersection of two lines is the laser beam point.**
- **According to the laser beam point to adjust its direction**



Observation results



realtime interface ranging to space debris



pre-processing interface

Number	Date	Objects	Time (UTC)	Perigee/km	Apogee/km	RCS/m2	Ranging	Returns
1	2011-09-14	20453	11:09:57~ 11:13:49	947	427	7.06	752~1114	249
2	2011-09-14	16612	11:19:44~ 11:22:33	632	609	4.14	682~1580	479
3	2011-09-14	17291	11:29:05~ 11:29:56	956	940	3.74	1238~1486	51
4	2011-09-15	23705	10:59:18~ 11:03:48	853	832	10.0	986~1393	481
5	2011-09-15	18749	11:34:34~ 11:35:43	638	609	4.64	852~1239	85
6	2011-09-15	20453	11:49:38~ 11:51:24	947	427	7.06	900~847	227
7	2011-09-15	25263	12:11:25~ 12:12:15	779	776	6.24	840~928	25
8	2011-09-15	20433	20:07:50~ 20:10:36	804	745	6.66	1159~891	160
9	2011-09-15	21610	20:29:22~ 20:30:32	763	758	14.17	1106~1104	44
10	2011-09-15	23343	19:57:28~ 9:59:43	649	640	12.26	770~1058	243
11	2011-09-15	24969	20:14:27~ 20:15:08	779	776	4.58	1324~1465	47

- **The operators have decreased (4 person before) during the measurement.**
- **The 8 passes were obtained during one night (only 2 passes in 2010).**
- **Have the capability to track space debris target up to 1800km.**
- **The successfully measuring passes of the space debris by our laser ranging system is about 50%.**

Utilization of high power laser at the frequency of 200-500Hz and Low Dark Noise Detector

- The new laser system of **diode pumped, 50-60W,200-500Hz, less than 10ns pulse width** will be utilized to observe space debris in near future.
- The low dark noise and high QE detector, APD, will also be used for inaccurate predicts of space debris.

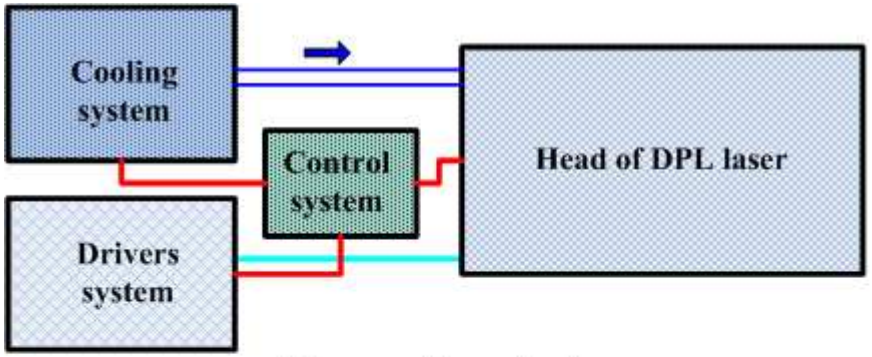
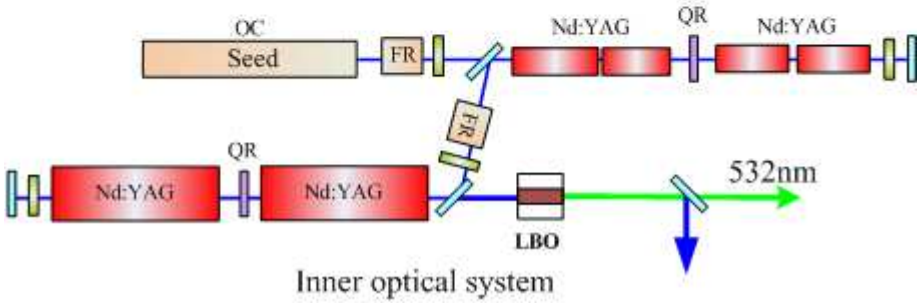
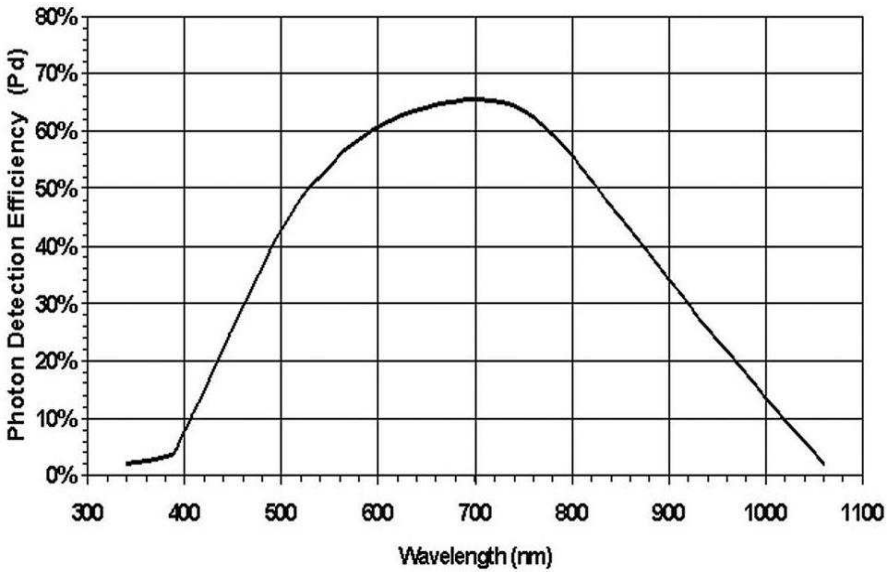


Diagram of laser structure



Inner optical system

Photon detection efficiency vs. wavelength of APD



Summary

- The laser returns from the space debris have been obtained firstly at the Shanghai SLR Station in July 2008.
- After years of system updating, the ability of laser ranging to space debris is being advanced and the numbers of measured passes are increased.
- As the development of laser ranging technology for space debris, some further improvements of measuring system need to be implemented in the further.
- The new high power laser system and lower noise detector, among the improvements, will be performed in the future to further enhance the ability of measuring system.


Thank you!