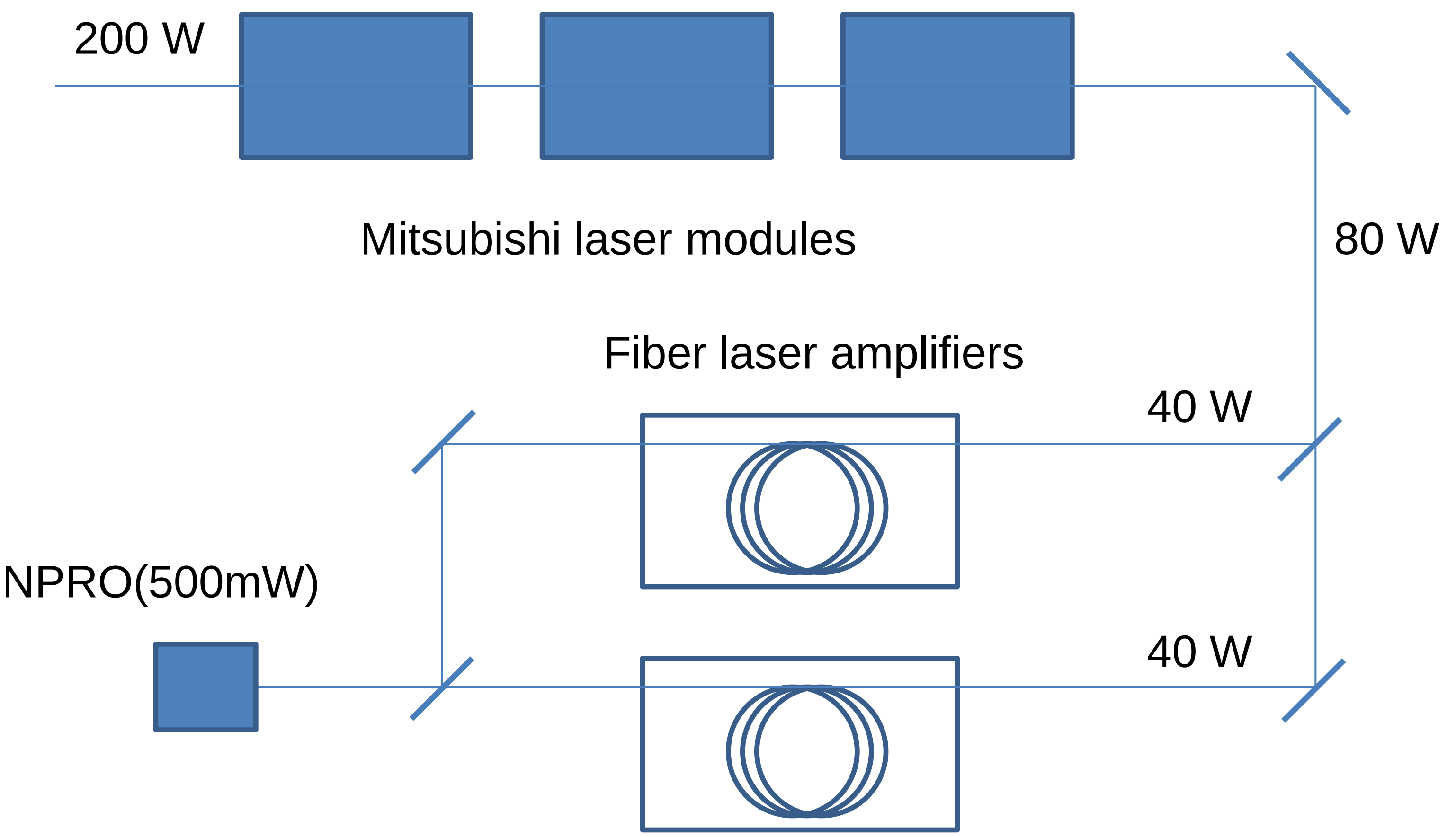
Development of the laser system for KAGRA

4th Korea - Japan Workshop on KAGRA

2013/06/10(Mon)

Schematic diagram

The output of the NPRO is lead to two fiber amplifiers.
Two outputs of the amplifiers are coherently added to obtain 80-W power.
The laser light is introduced into three-stage solid-state amplifiers in order to obtain 180-W output power.



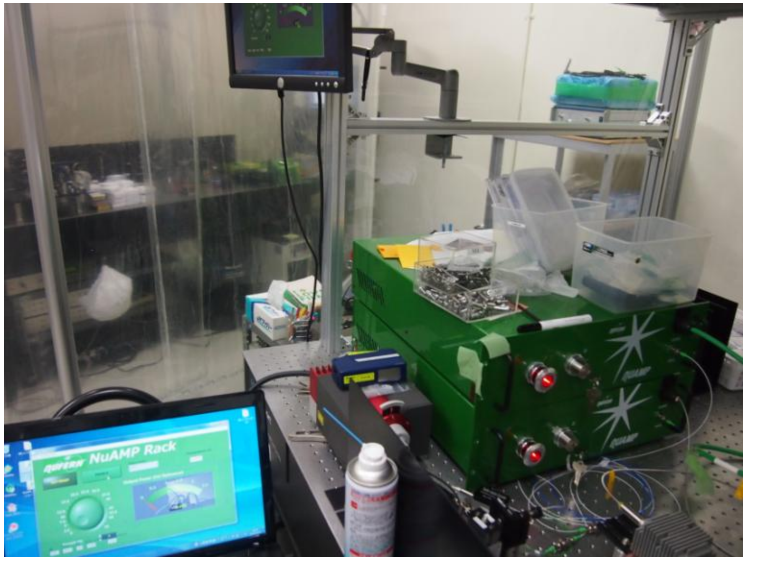
After the 3rd Workshop

- We have improved the efficiency at the coherent addition; the obtained power was incireased from 64 W to 78 W.
- We have also achieved the long term operation (4hours).
- We have done the experiment to measure and correct the wave-front distortion caused in solid-state amplifiers.

Coherent addition

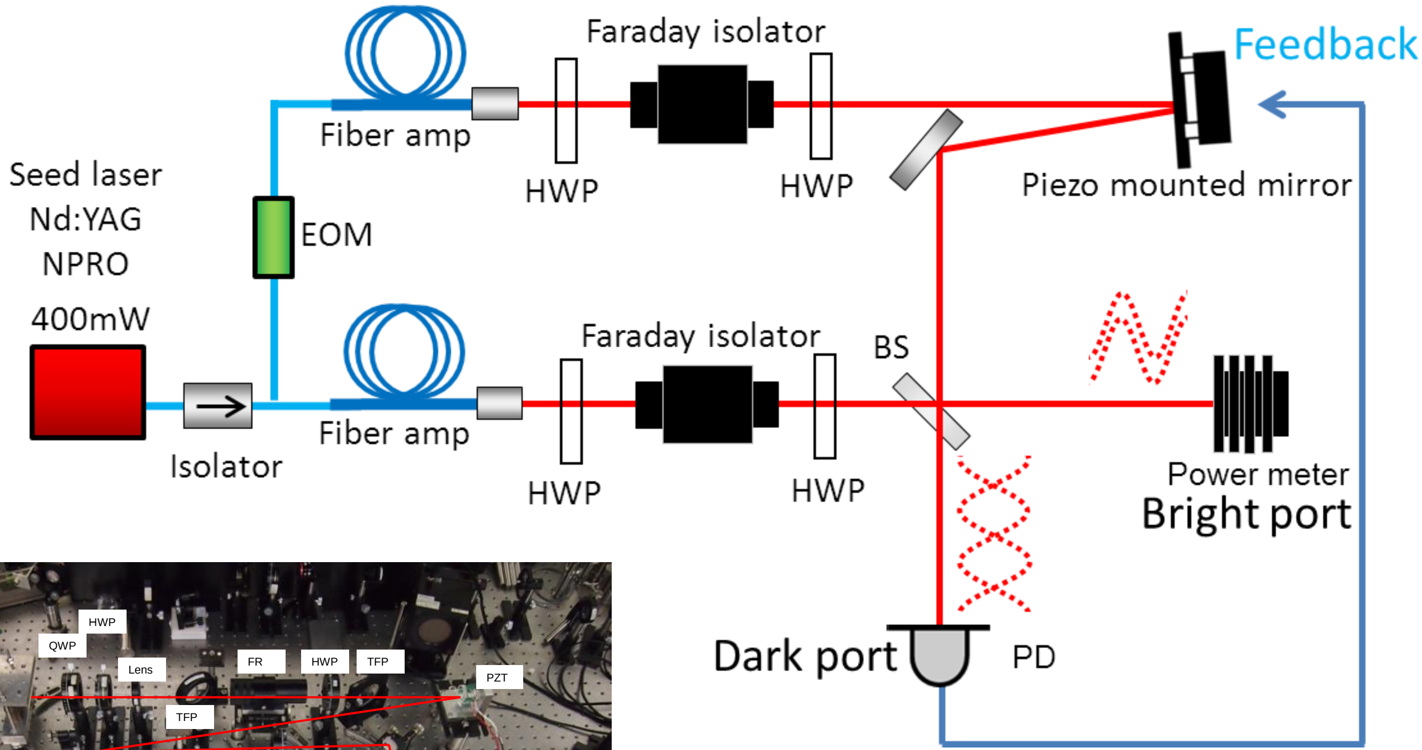
Why coherent addition

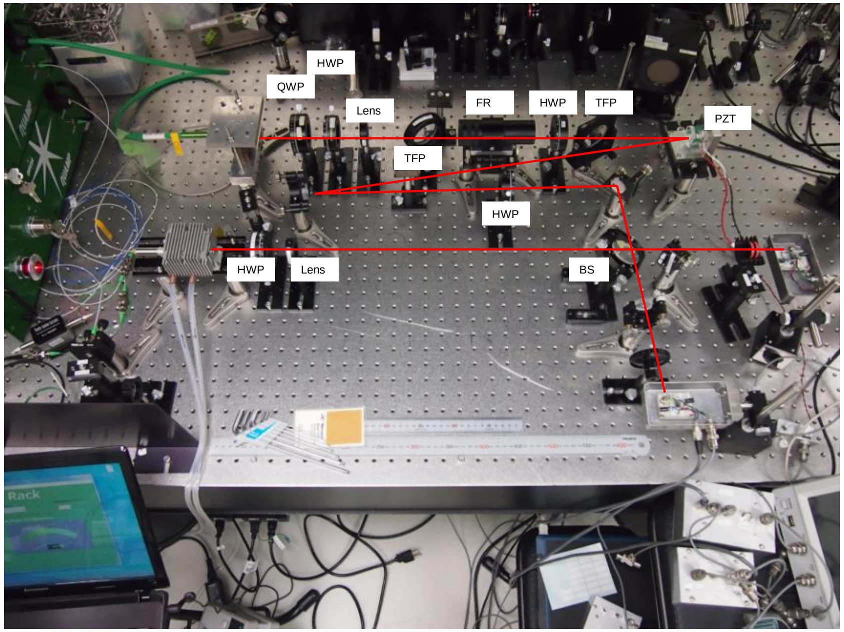
- Narrow bandwidth amplification by a fiber-laser amplifier cause non-linear effects resulting in degrading the stability of laser light.
- Coherent addition may solve the above problems; each laser can keep its good performance.



Two commercial fiber-laser amplifiers (40-W) and a seed laser (NPRO, 500mW)

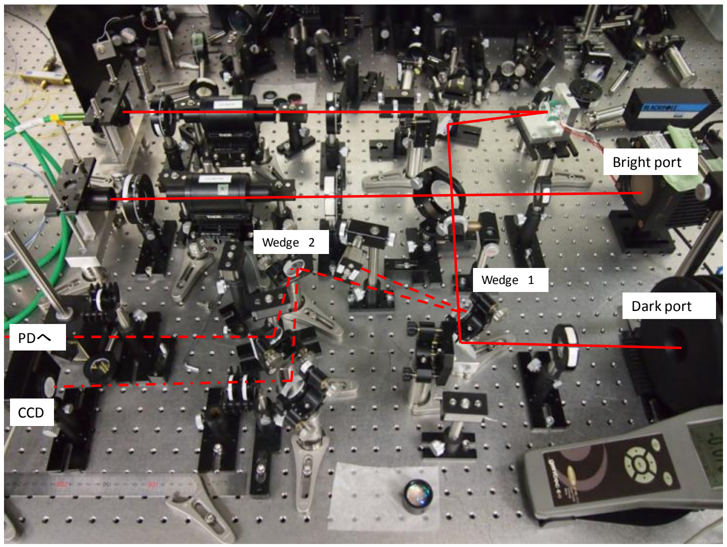
Coherent addition of two laser outputs





3rd Workshop (2012.12.21)

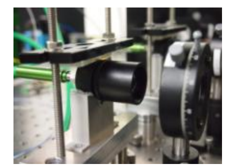
Optical system



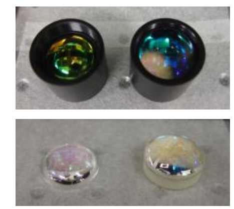
The highest power was 64 W that was obtained from two 40-W outputs.

The limitation factor in coherent addition

- At low power, we could obtain rather high visibility at the addition port. However, when the power became high, the visibility was degrade; this seemed to be caused by the imbalance between two output optics set for the fiber outputs.



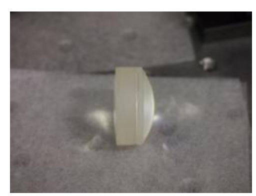
Output collimator



Different collimator lenses made of BK7.

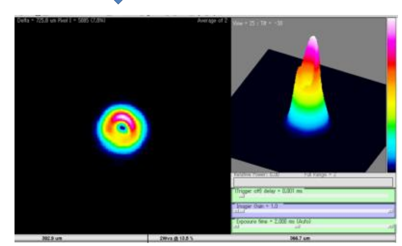
One of the lenses shows unusual behavior when the high power laser light is incident

Bad lens



This one shows very large thermal lens effect.

Focused beam shows doughnut-shape intensity distribution.

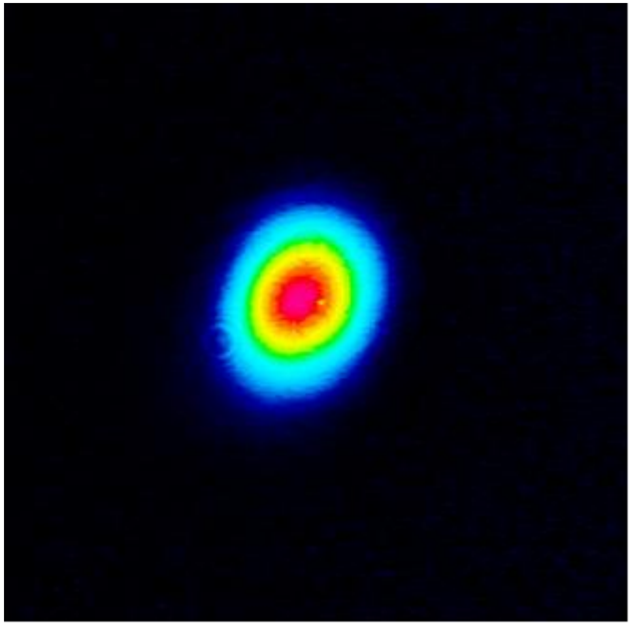


Finally, we have obtained a good lens pair.

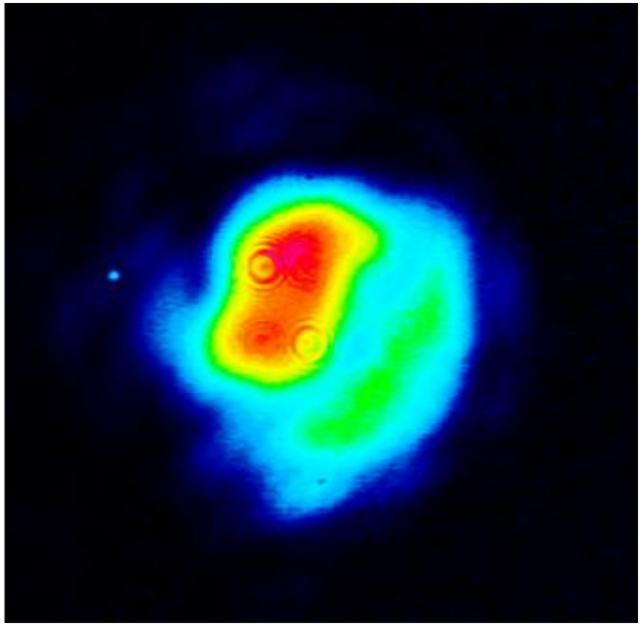
We should replace the lens to obtain better visibility.

Result of the coherent addtion

41W × 2 =>**78W Efficiency 95%**

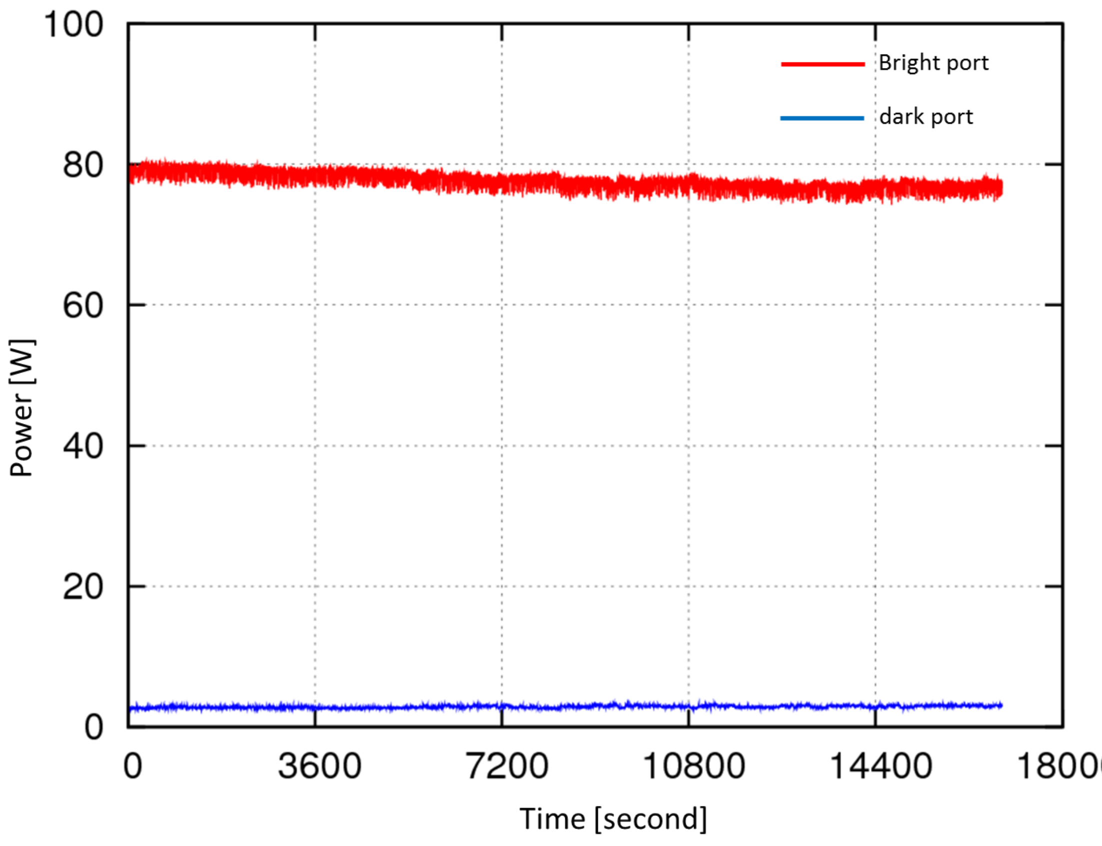


Bright port 78W



Dark port 4W

Long-term operation



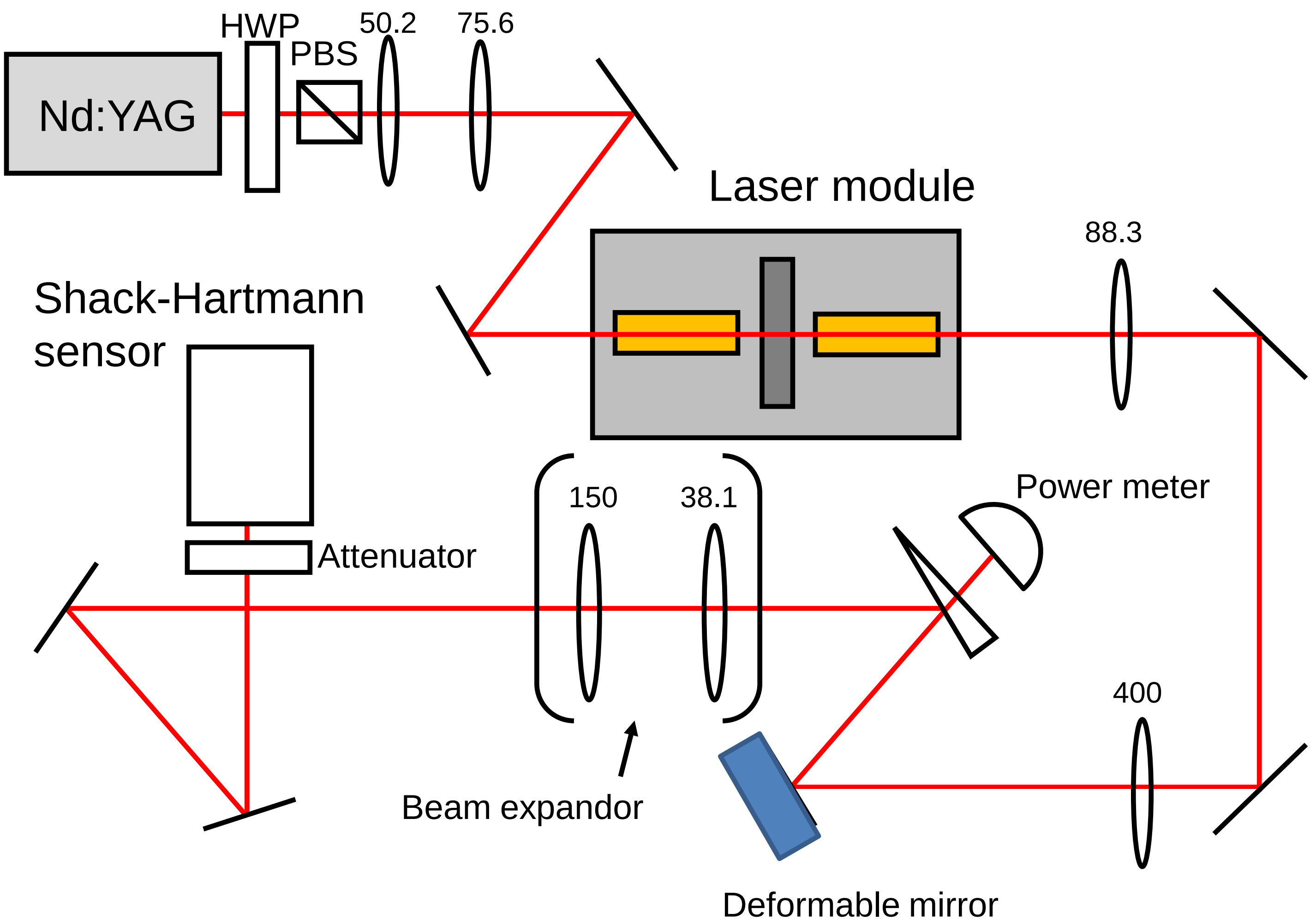
Continuous Locking has been maintained over 4 hours.

Measurement and correction of Wave-front distortion

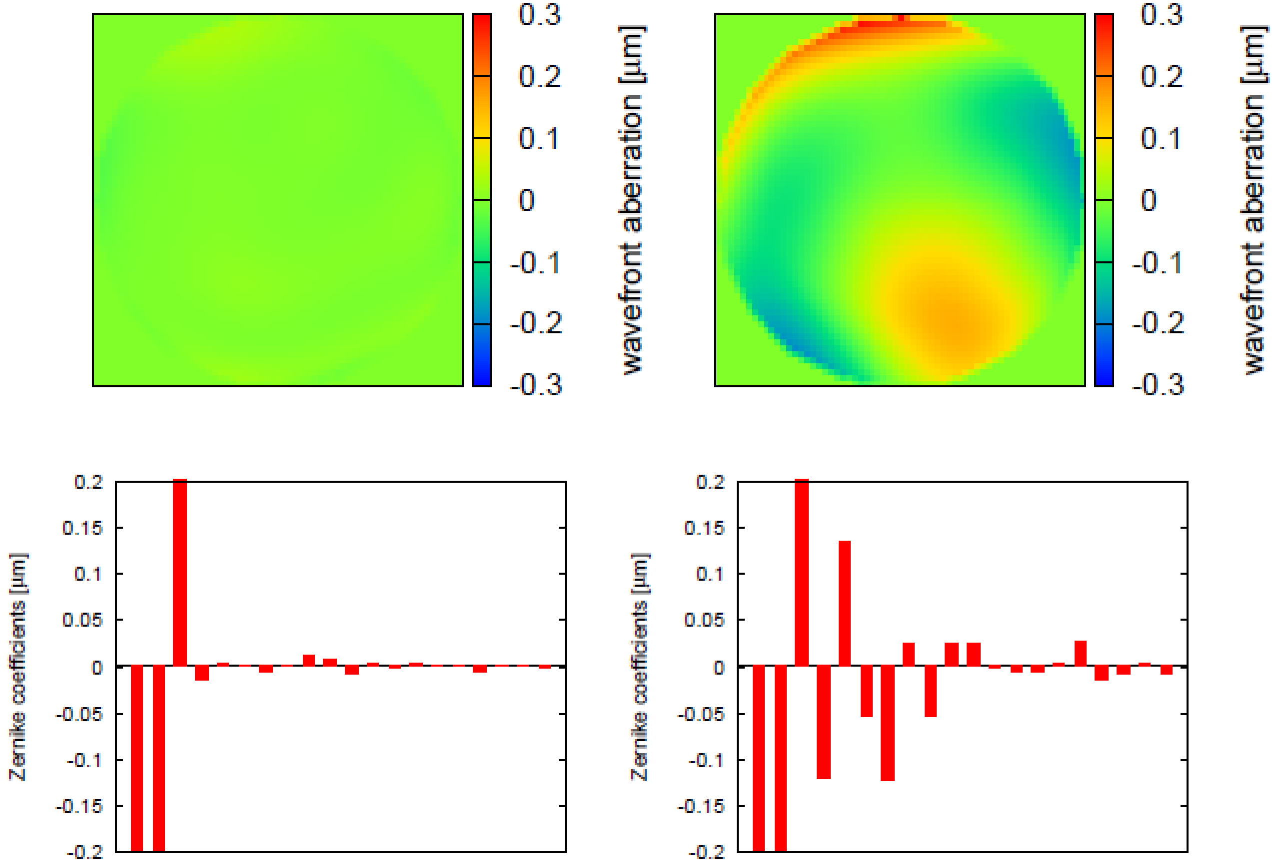
Wave-front distortion by solid-state amplifiers

- Wave-front distortion is caused by solid-state amplifiers owing to
  - Imperfect laser crystal
  - inhomogeneous pumping.
- We are making an experimental system that can measure and correct the wave-front distortion.

Optical system



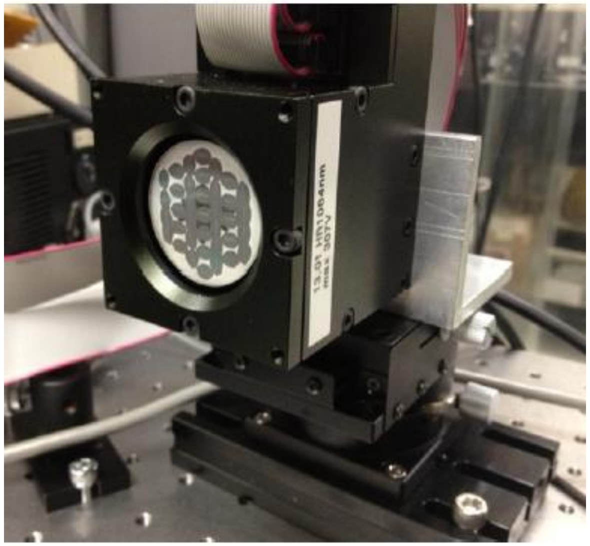
Wave-front distortion

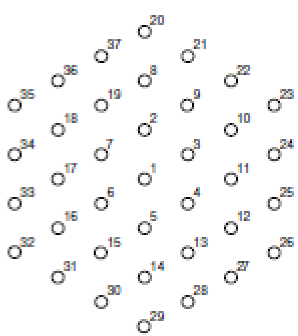


(a) 0A

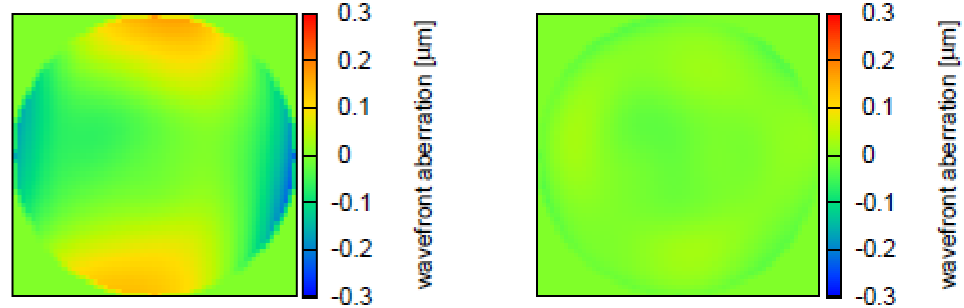
(b) 37.5A

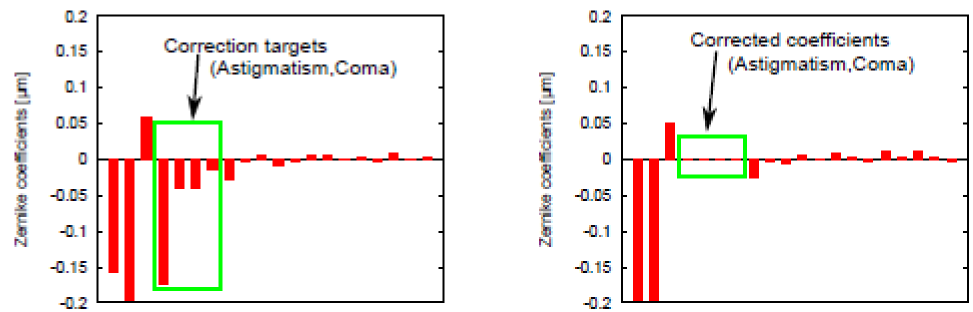
Wave front correction





Deformable mirror:
37 actuators





(a) Before

(b) After

	Before pumping	After pumping	After correction
Strehl ratio	0.997	0.75-0.82	0.994

Summary

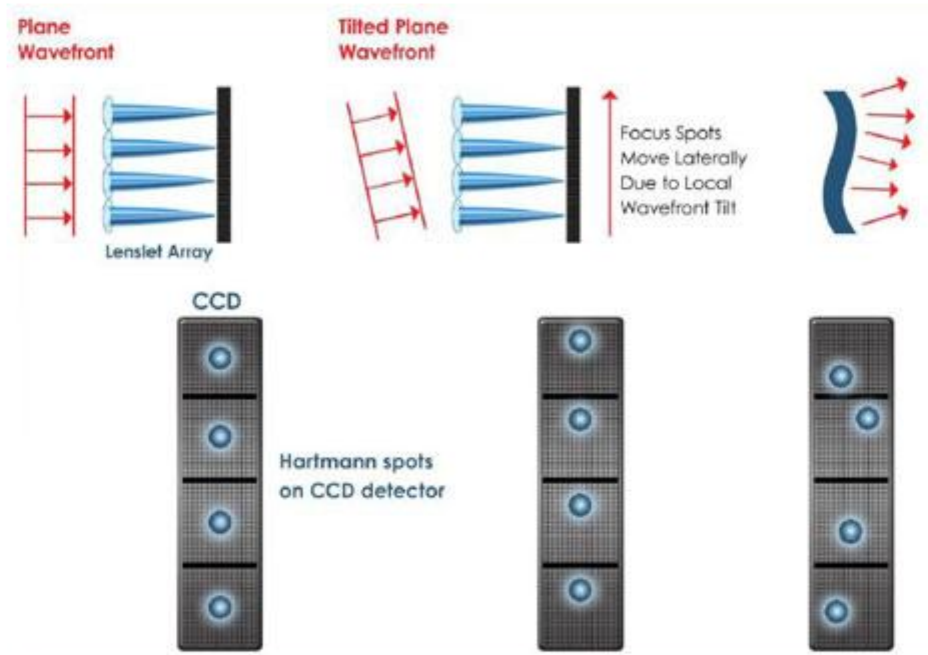
- Preparation of the laser system is going on.
- The performance of the fiber laser amplifier and the coherent addition is almost satisfactory.
- Several improvements are being done; the change of the chiller, introduction of fiber stretchers and so on.
- Wave front corrections have been done.

Fiber-ring cavity experiment

- Prof. Yoon and his student (Byunghyuk Moon) will stay at ICRR.
- We are preparing a fiber-ring cavity experiment under the collaboration with them.
- The key devices (low-loess fiber couplers) have been delivered to us.

Shack-Hartmann sensor

- Using an array of miniature lenses called "lenslets," the sensor splits light into a number of small beams which is then focused onto a CCD camera.
- As the incident wavefront is aberrated by the lenslet, the focused spot on the CCD camera moves.



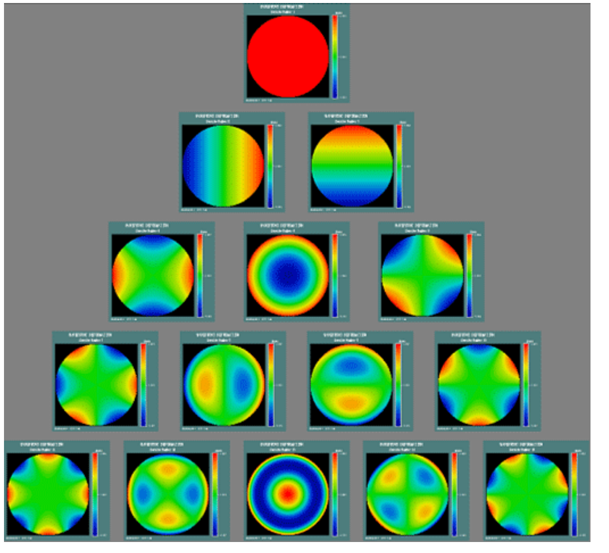
Zernike polynomials

The Zernike polynomials are a sequence of polynomials that are orthogonal on the unit disk.

$$W(x,y) = W(\rho\sin\theta, \rho\cos\theta) = W(\rho,\theta)$$

$$= \sum_{n=0}^{k}\sum_{m=0}^{n} A_{nm} \cdot R_n^{n-2m}(\rho) \cdot \begin{cases} \cos|n-2m|\theta & : n-2m \geq 0 \\ \sin|n-2m|\theta & : n-2m < 0 \end{cases}$$

$$R_n^{n-2m}(\rho) = \sum_{s=0}^{m} (-1)^s \frac{(n-s)!\,\rho^{n-2s}}{s!(m-s)!(n-m-s)!}$$



The outputs of the Shack-Hartmann sensor are given by the magnitude of the coefficients of Zernike terms