Amplifier with high energy capacity and average power based on cryogenically cooled disk shaped Yb:YAG laser ceramics

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Contents

- Introduction
- Master oscillator and a preamplifier system
- Milestones in the main amplifier evolution
- Conclusion

Advantages of Yb doped cryogenically cooled thin disk active element

- Yb dopping

1. Low quantum defect ~8,5%
2. Long lifetime ~ 1 ms
3. No upconversion`

- Thing disk

1. Effective heat removal
2. No self-focusing
3. Multi-pass geometry

- Liquid Nitrogen cooling

1. Emission and absorption cross sections increase
2. 4-level scheme
3. Heat conductivity increase
4. Thermoptical properties improvement

- Ceramic active elements

1. Larger apertures
2. Ability to use Yb:X_2O_3
3. Higher damage threshold

Basic parameters of projected laser system

Projected parameters

1. 0.5J in ~100 ps pulse
2. 1 ms lifetime -->1 kHz repetition rate
3. 500 W average power, M^2 ~1-1,5

Seed laser at 1029.3 nm

- Yb:YAG disk laser
- 100 ps or 20 ns pulse,
- Optionally Yb:YAG regenerative amplifier
- 1-5 mJ pulses at 1kHz repetition rate

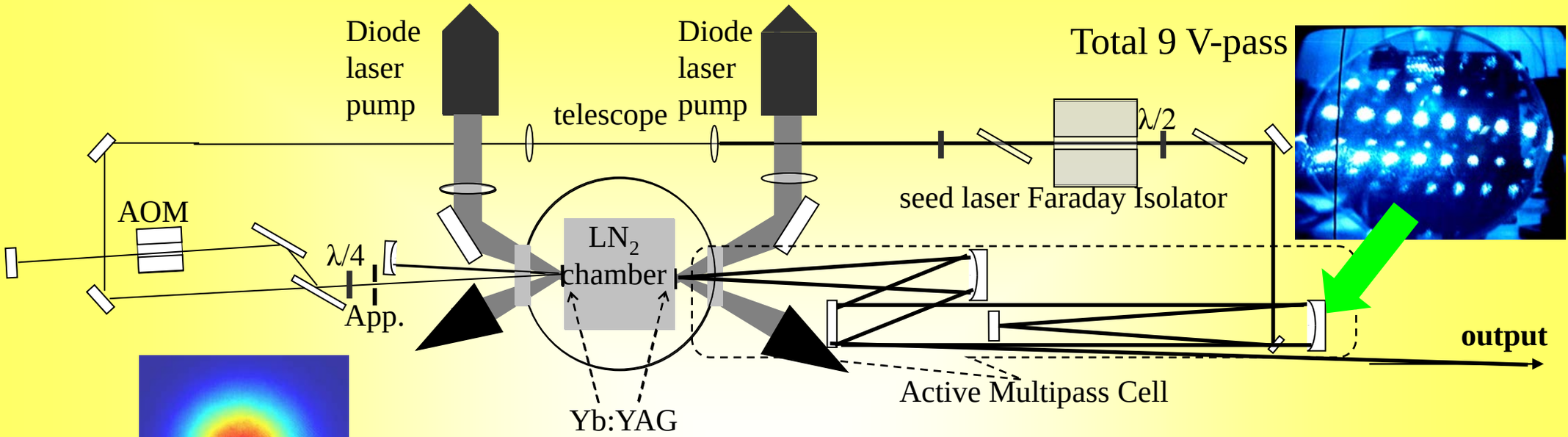
Cryogenic disk preamplifier

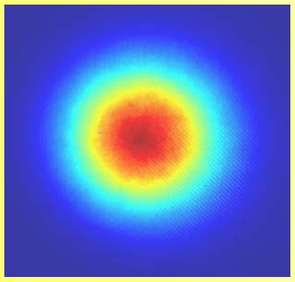
- The Yb:YAG active mirror, 1-5 mJ seed pulse energy, 50 mJ amplified pulse
- 16(32) passes of the beam with D = 3-4 mm, small signal amplification a_0L=0.4-0.6
- 150-300 W pump power, 77 K temperature
- The stored energy about 100 mJ

Cryogenic two disks main amplifier

- Two Yb:YAG active mirrors, 500 mJ amplified pulse
- 8(16) passes of the beam with D = 8-12 mm, small signal amplification a_0L=0.25-0.45
- 2×(08-1.2) kW pump power, 77 K temperature
- 2 ×(0.5-0.7) J of stored energy

MOPA system

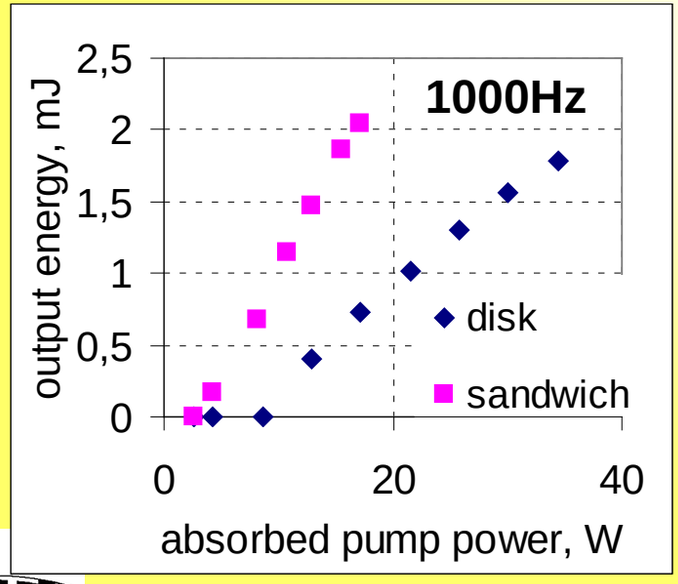


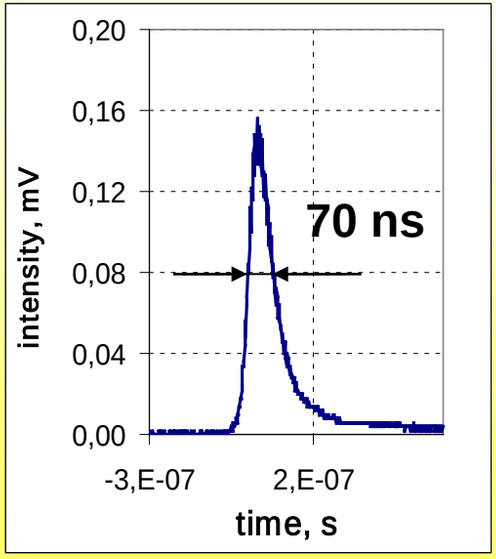


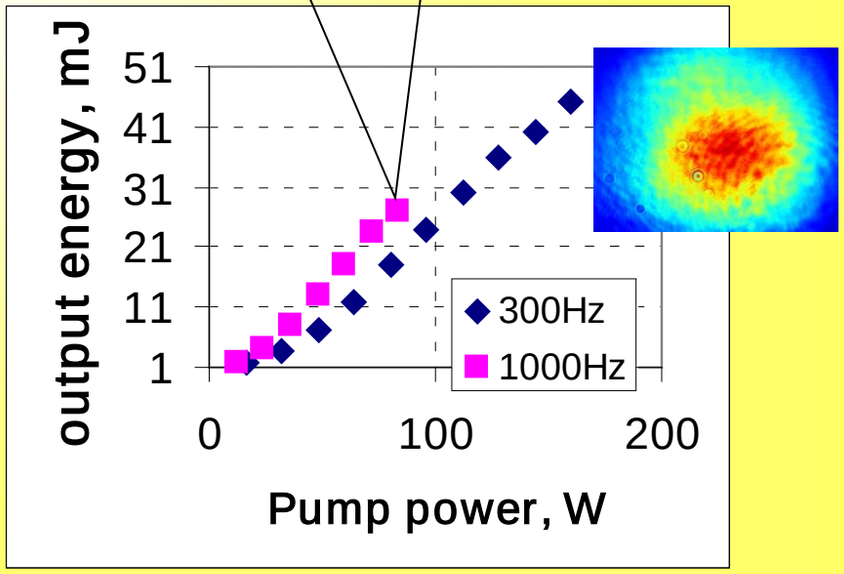
Beam from the MO

•Excellent stability of the MO: it's close to 1% through 2 hours!

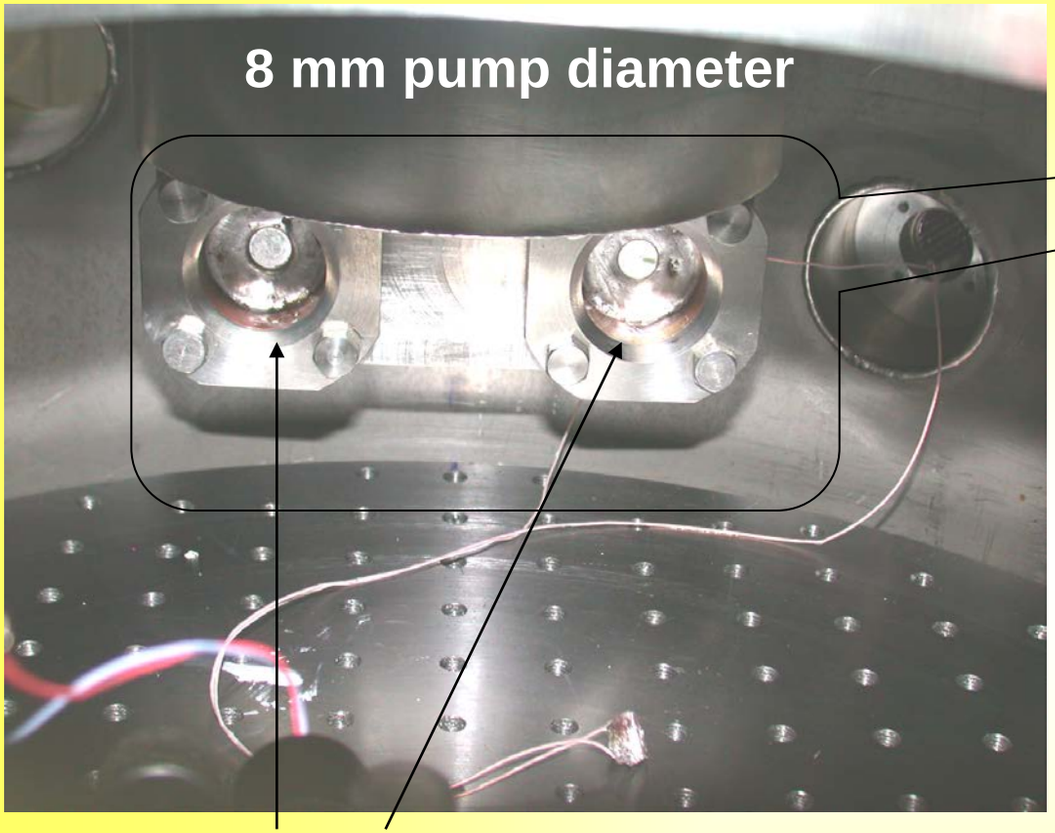
High o-to-o efficiency ~33%



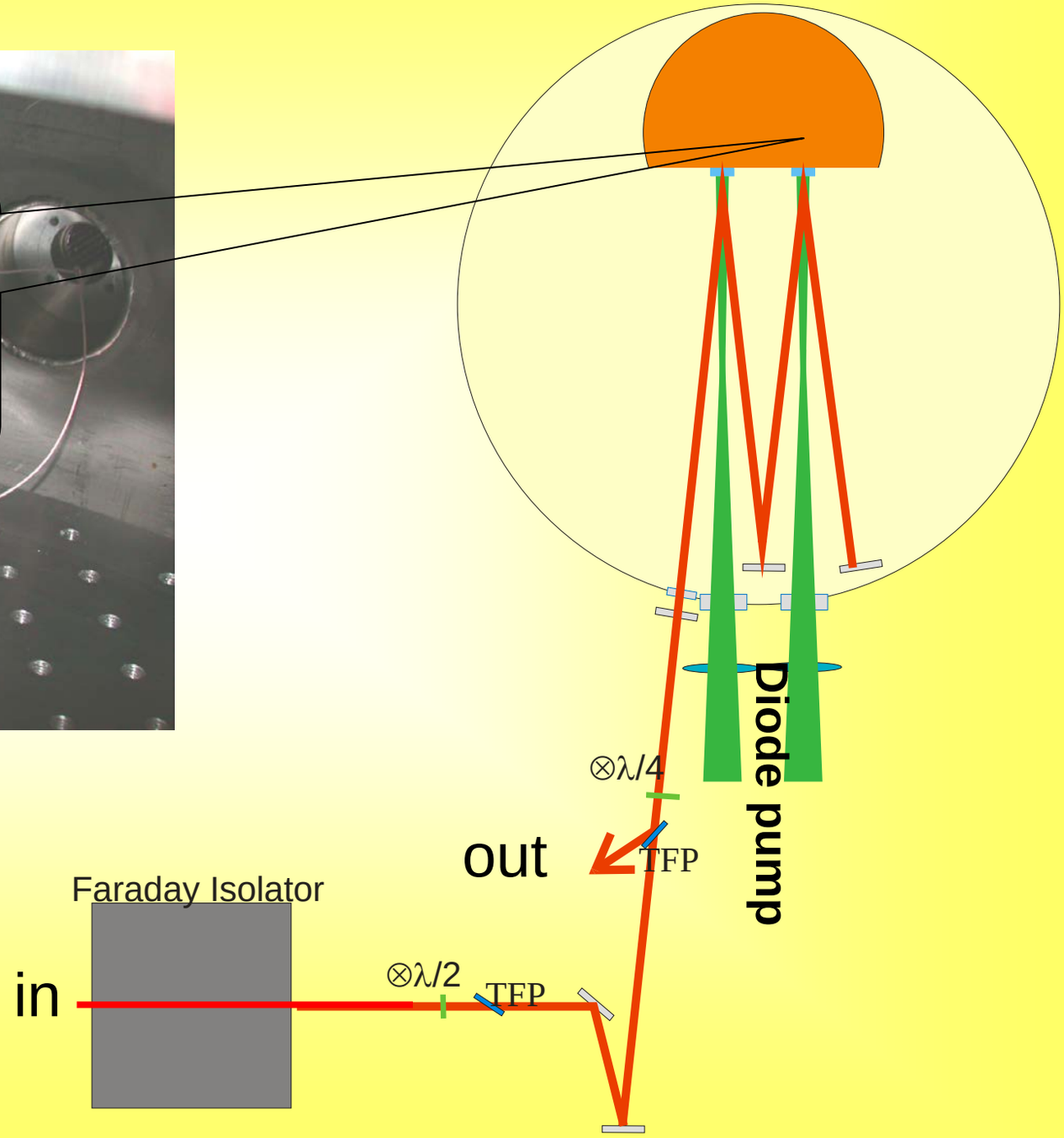




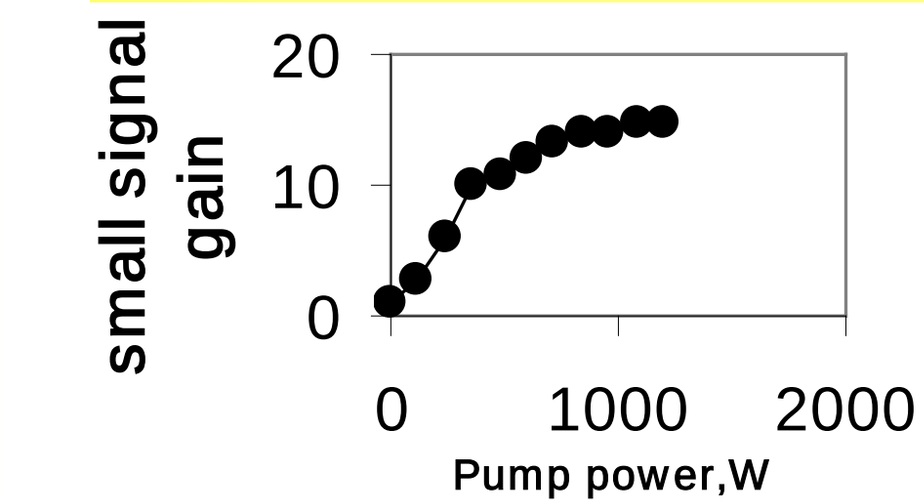
Scheme of the main amplifier

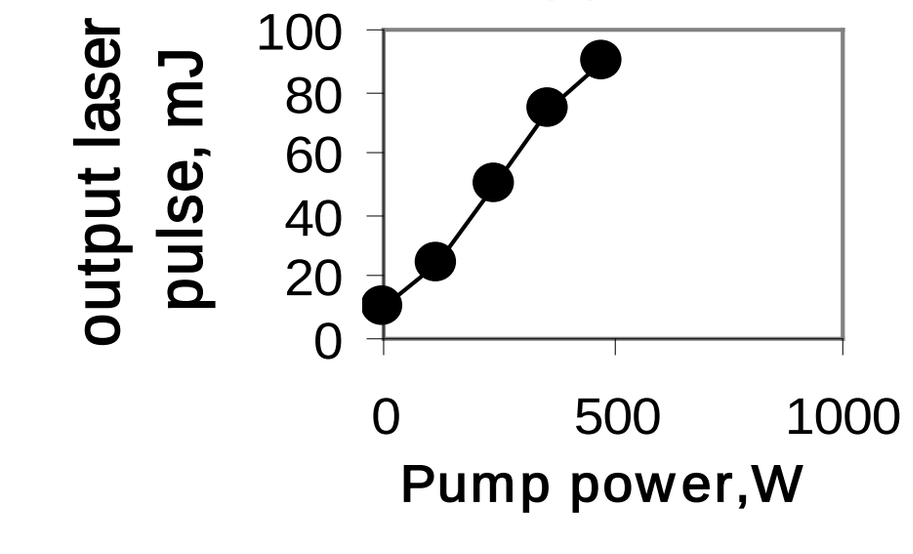


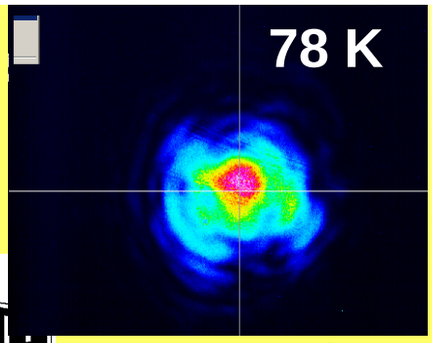
Active elements

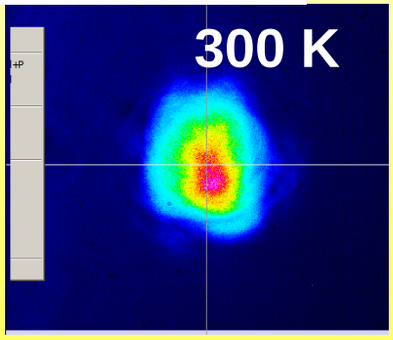


4W-pass 2 disk main amplifier at 200Hz

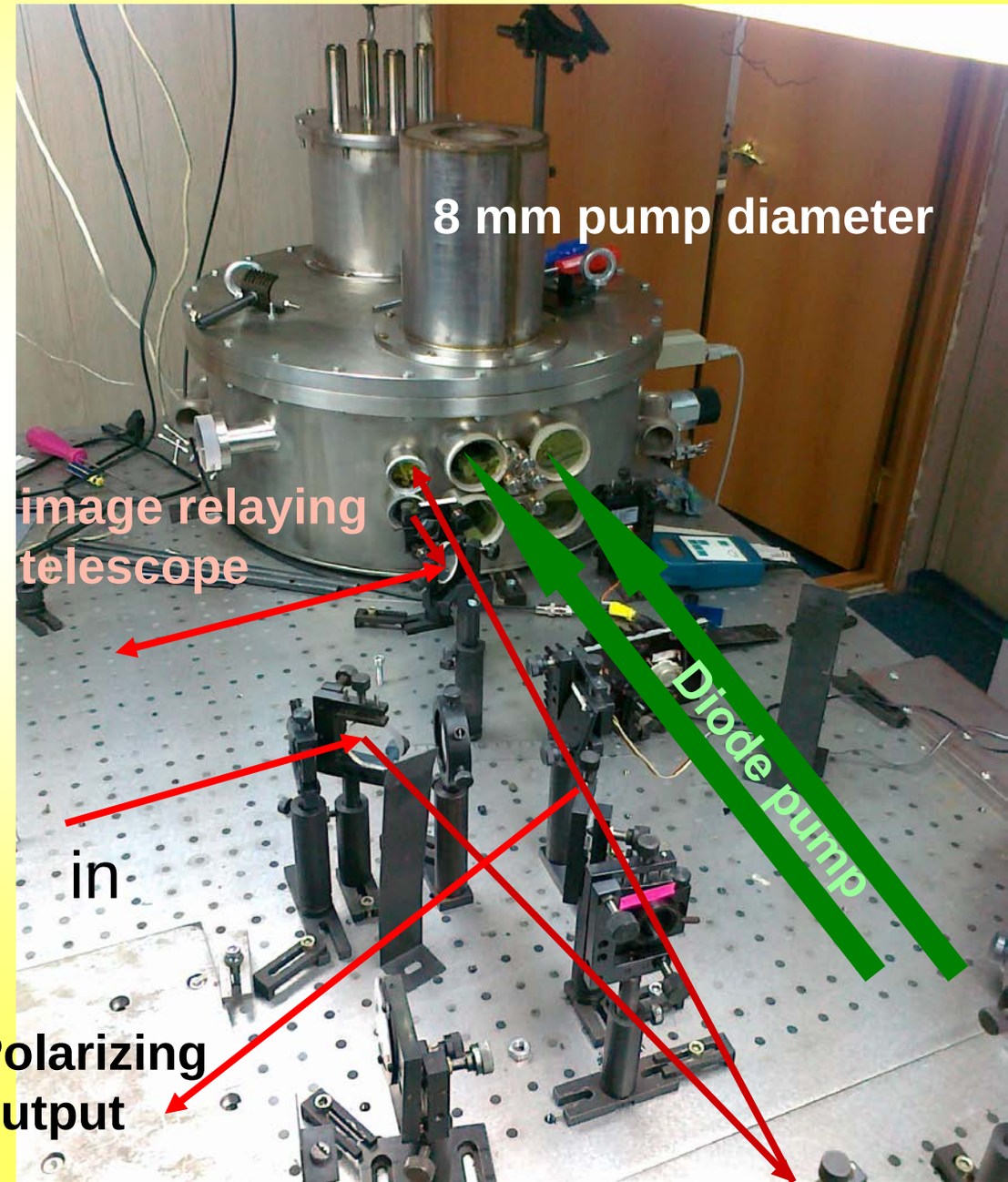








0.2kHz 20% duty circle pump



The 1st upgrade of the main amplifier

Large losses (>50% for 2W passes) and pour beam quality because of

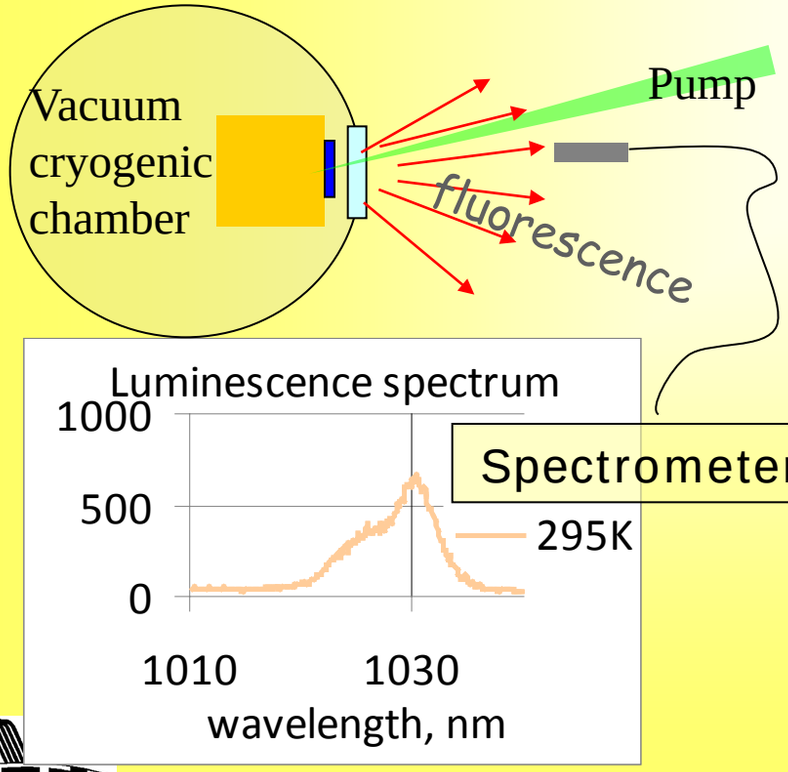
- leakages in the cryogenic chamber → Nitrogen gas flow for the AE surface protection from the condensate → Good AR coating

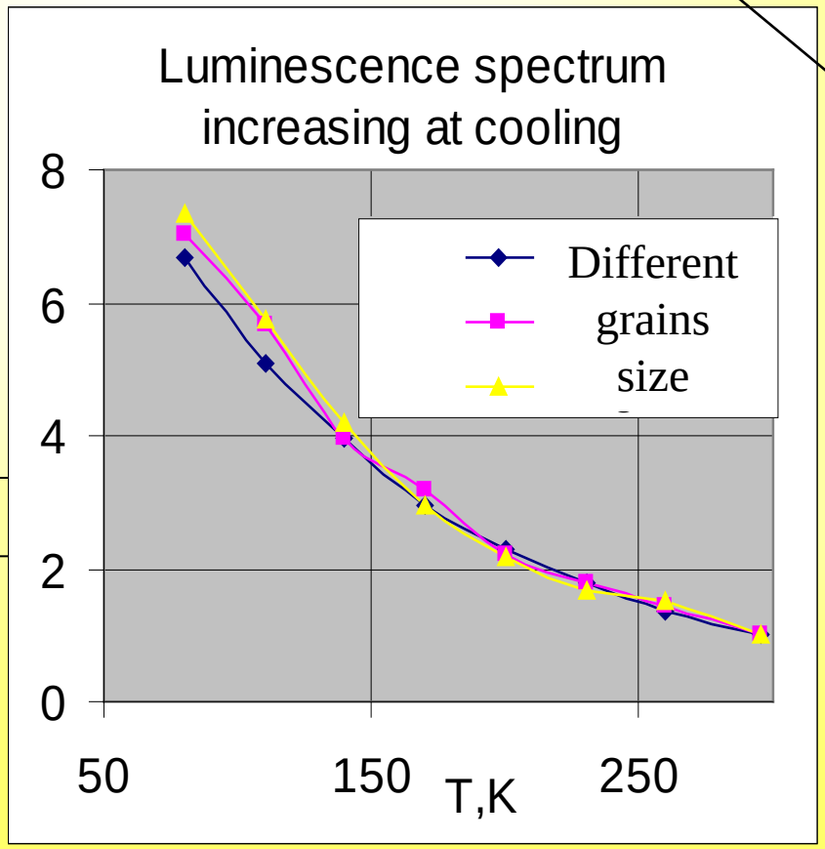
- "bad" Yb:YAG medium (low thermal conductivity at 80K, additional absorption) → 10% 900μ thick Yb:YAG crystal → Mechanical strength

- disk bending

5% 1400μ thick Yb:YAG ceramic → Losses ~80% (due to scattering)

Lower heat sink





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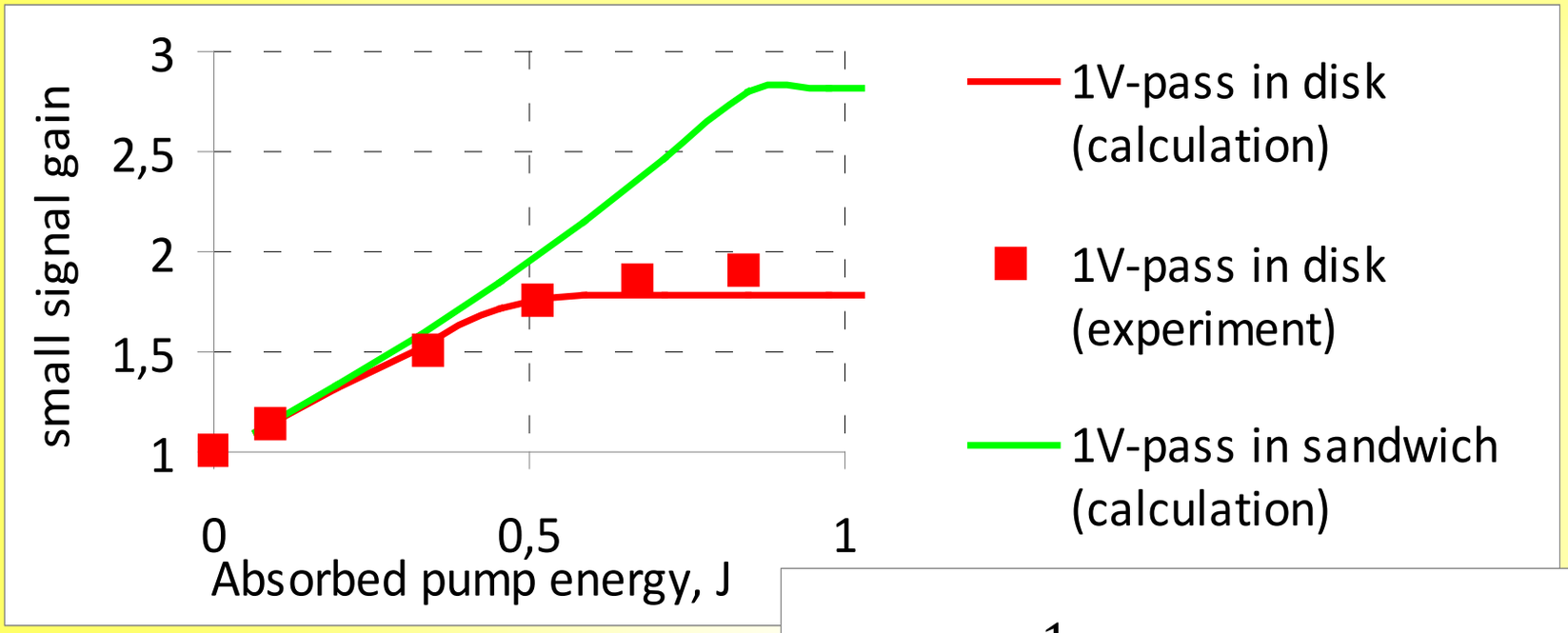
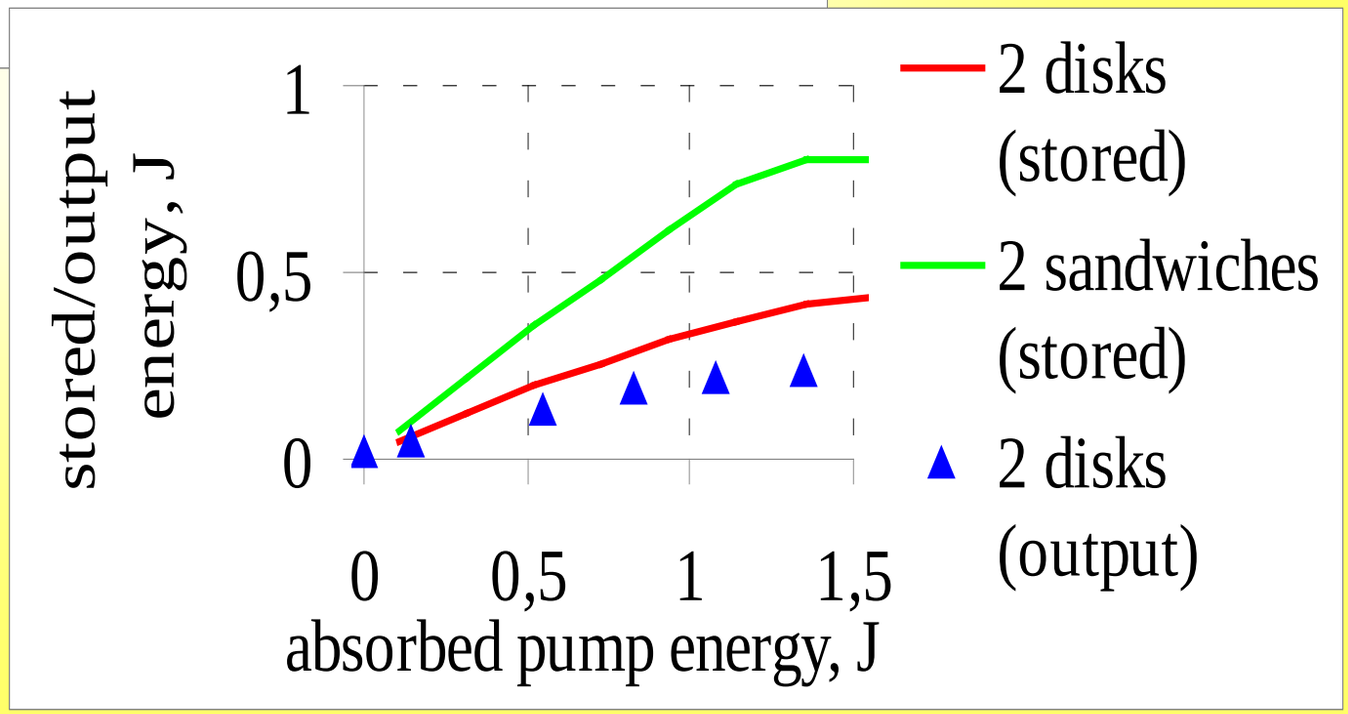
4W-pass 2 ceramic disk main amplifier with 233mJ at 143Hz



High otical-to-optical efficiency ~ 20%

Extracted ½ of stored energy

3D Numerical calculation, taking into account ASE, by Olga Vadimova (previous) talk)



The 2d upgrade of the main amplifier

Yb:YAG/YAG composite active elements

SSG 1.9 per disk

0.2J of stored energy

SSG 2.8 per disk

0.4J of stored energy

Our new technique of thermal bonding, Ivan Mukhin

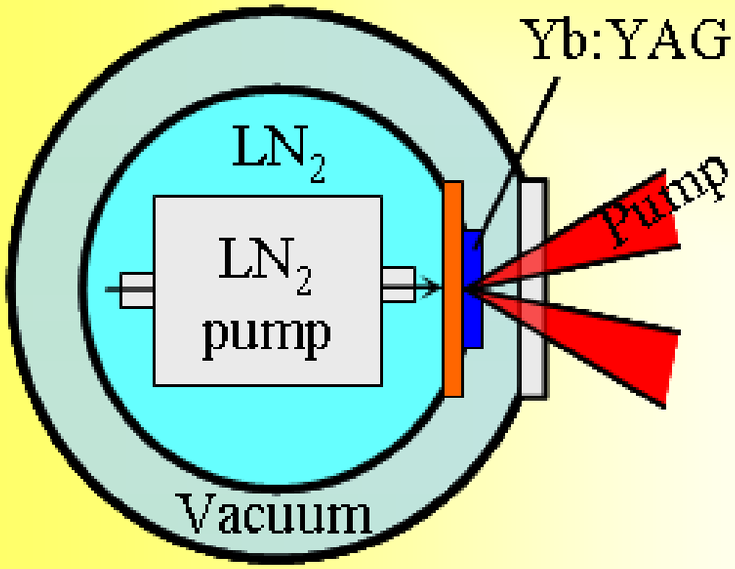
Amplified spontaneous emission reducing

High mechanical strength

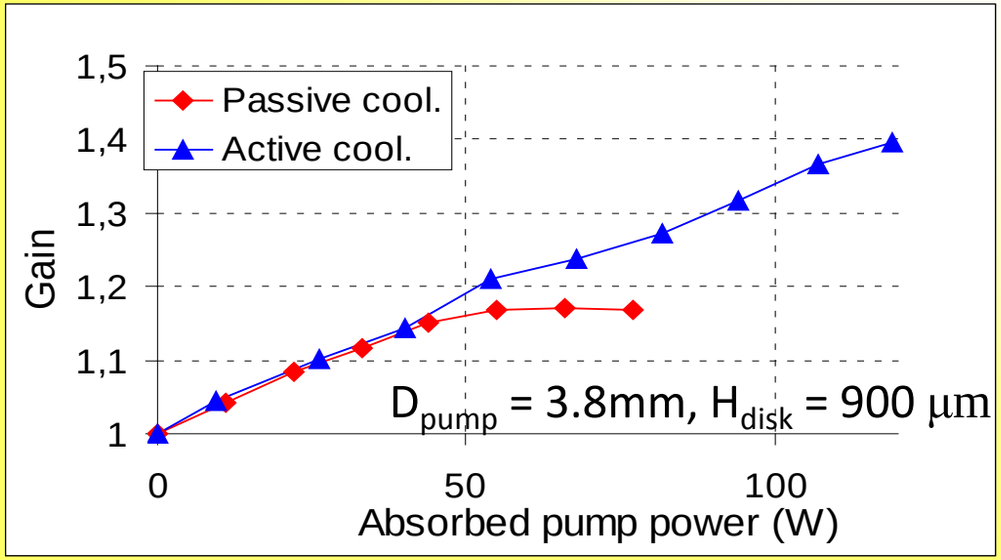
- Yb:YAG crystals without losses

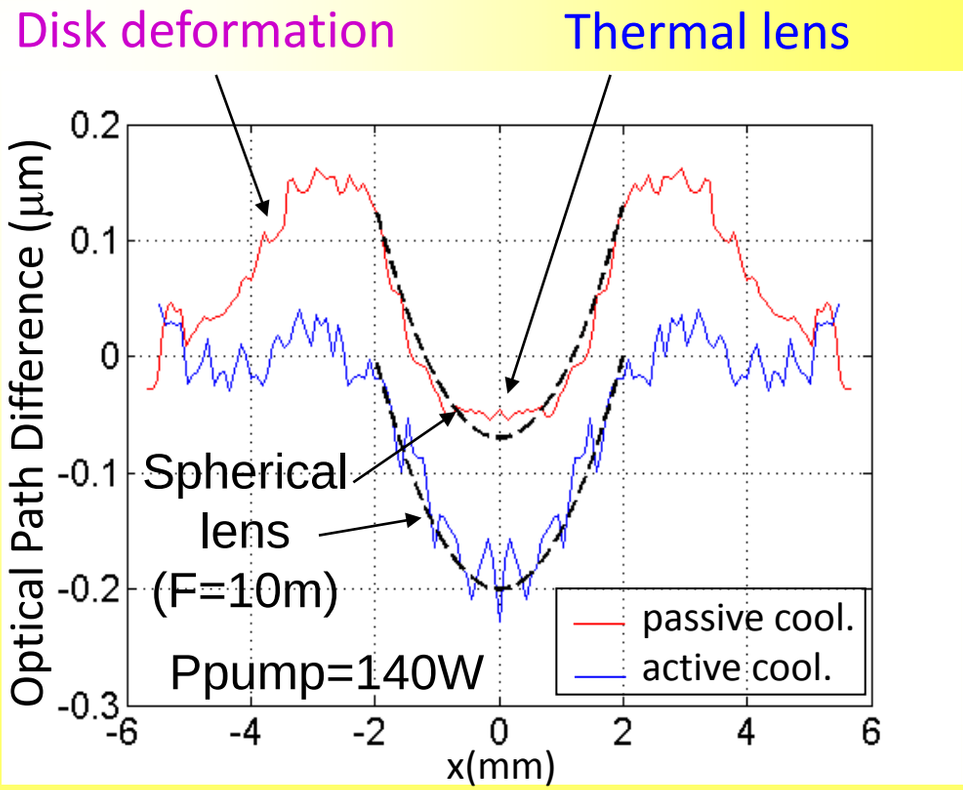
The 2d upgrade of the main amplifier

Active cryogenic cooling system

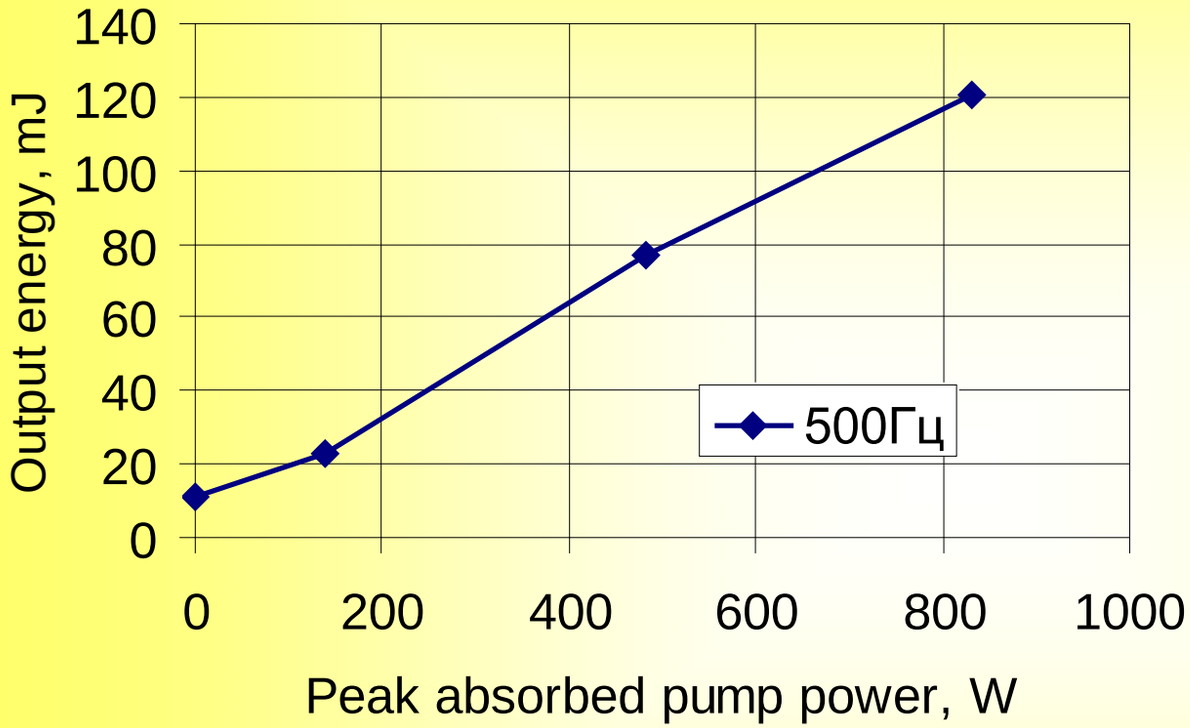


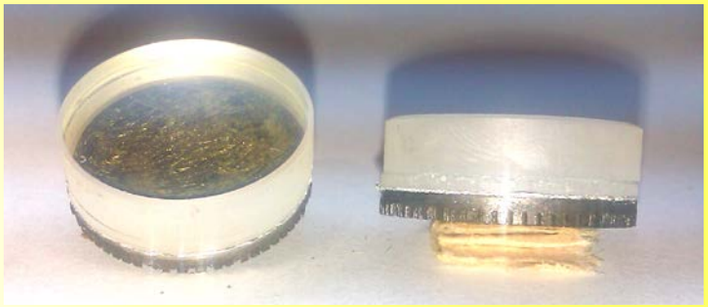
The pump is placed into the reservoir with liquid nitrogen, it's output pipe is turned on the radiator.





4W-pass 2 Yb:YAG/YAG composite disk main amplifier with 120mJ at 500Hz





Optical-to-optical efficiency ~ 12%

Average power

60W

Short-range plans

- **Experiments with ceramics composite active elements**
- **Application of an active multipass cell scheme in the main amplifier**

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Conclusion

- We reached 233mJ at 143 Hz (o-to-o efficiency ~ 20%) in the output with 70ns 30mJ input pulses. In such a way we extracted somewhat half of stored energy. To our knowledge, this output result is the best among all cryogenic pulsed Yb:YAG ceramic and Yb:YAG disk monocrystal laser systems
- Using composite Yb:YAG/YAG active elements and an active cooling system 120mJ at 500 Hz (60 W of the average power) is archived at the output of the system.
- For the optimization of the output parameters we plan to use an active multipass cell scheme in the main amplifier

Thank you for your attention

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