Narrow band ytterbium-doped fiber laser as source of termal light

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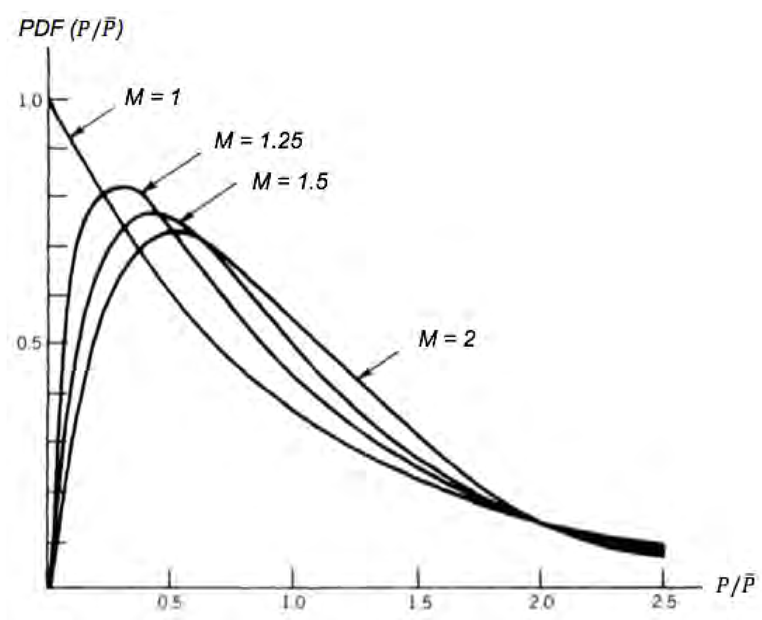
Abstract: In this work we report spectral and noise features of the signal for a moderate power double-clad ytterbium-doped fiber laser (YDFL) assembled in Fabry-Perot cavity configuration, as well as the changes suffered on its photon count statistics with the increase of laser power, for polarized and non polarized light., in order to identify the conditions under it can be considered as thermal light.

Thermal light sources

These sources are described by M-fold Bose-Einstein distribution, where M is related to the number of independent states of ASE.

$$P(n,\bar{n},M) = \frac{(n+M-1)!}{n!(M-1)!}\frac{(\bar{n})^n}{(1+\bar{n})^{n+M}}$$



where $P(n,\bar{n},M)$ is the probability of counting n ASE photons by photodetector, and $\bar{n}$ is the mean photon count [1].

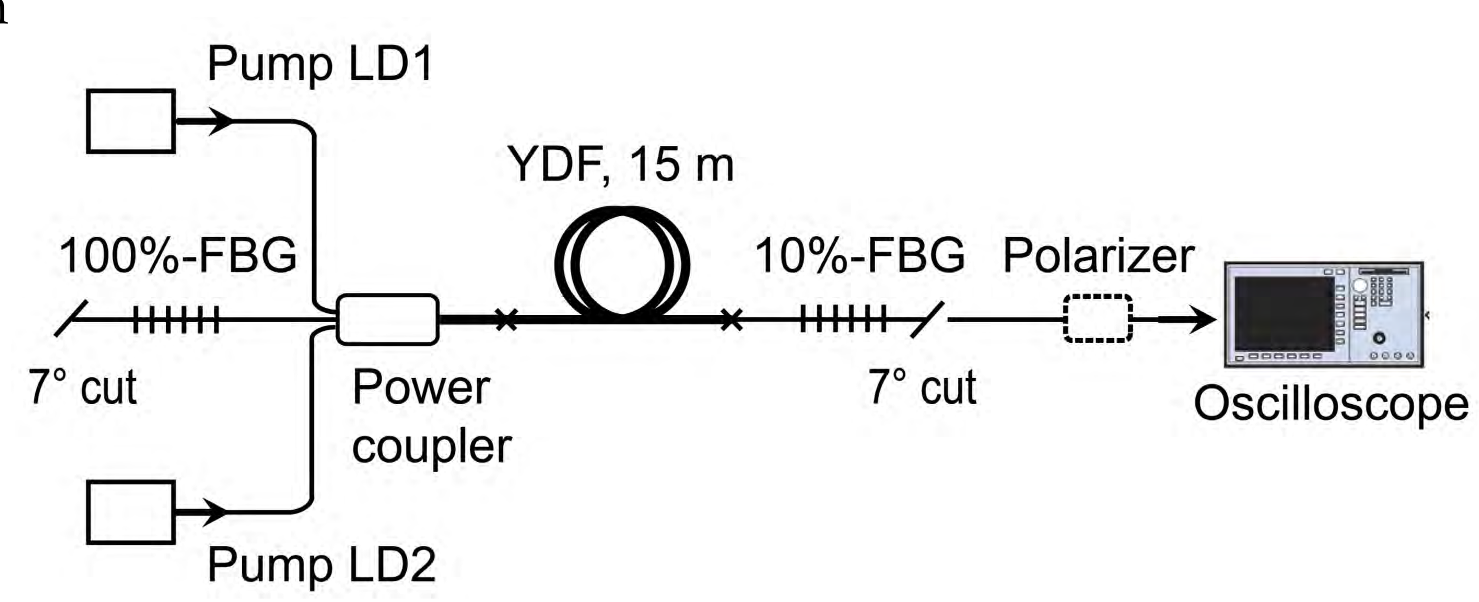
For YDFLs, nonlinear fiber length has to be considered: $L_{NL} = (\gamma P)^{-1}$, where $\gamma = n_2\omega/(cA_{eff})$ is non-linear parameter, n_2 is nonlinear refractive index, ω is light angular frequency, and $A_{eff} = \pi\,(MFD/2)^2/2$ is the effective area of laser Gaussian beam [2].

[1] J. W. Goodman, "Statistical optics" (Wiley, NY, 2000).

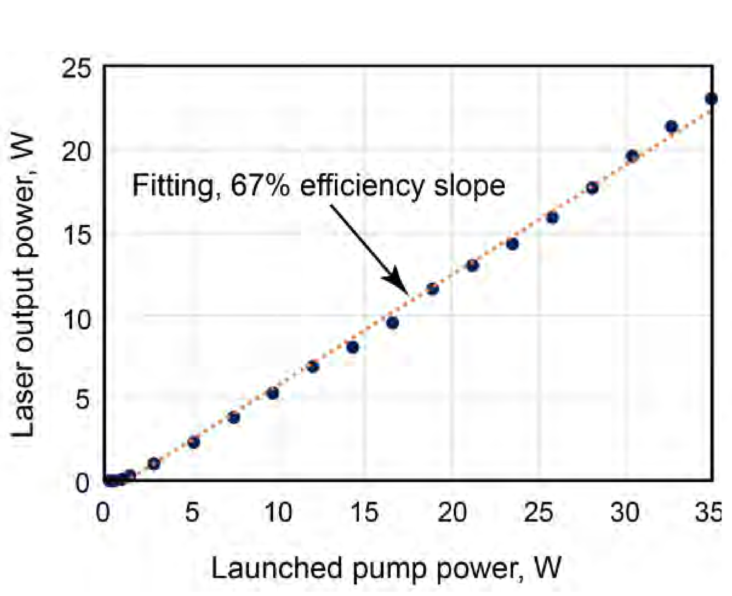
[2] G. P. Agrawal, "Non-linear fiber optics" (Academic, CA, 2001).

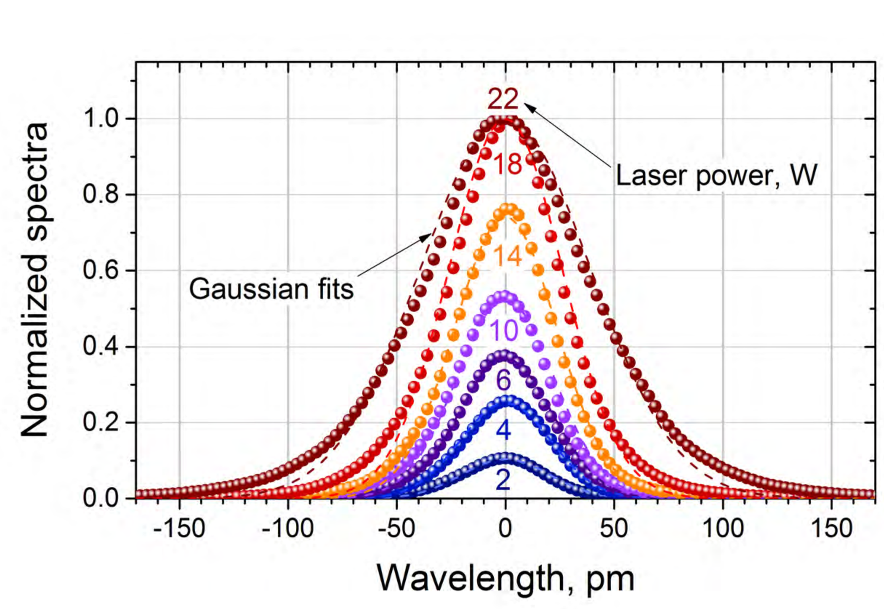
Experimental Setup

Experimental setup of the YDFL is based in a Fabry-Perot cavity composed by two fiber Bragg reflectors (FBG) centered on 1061 nm



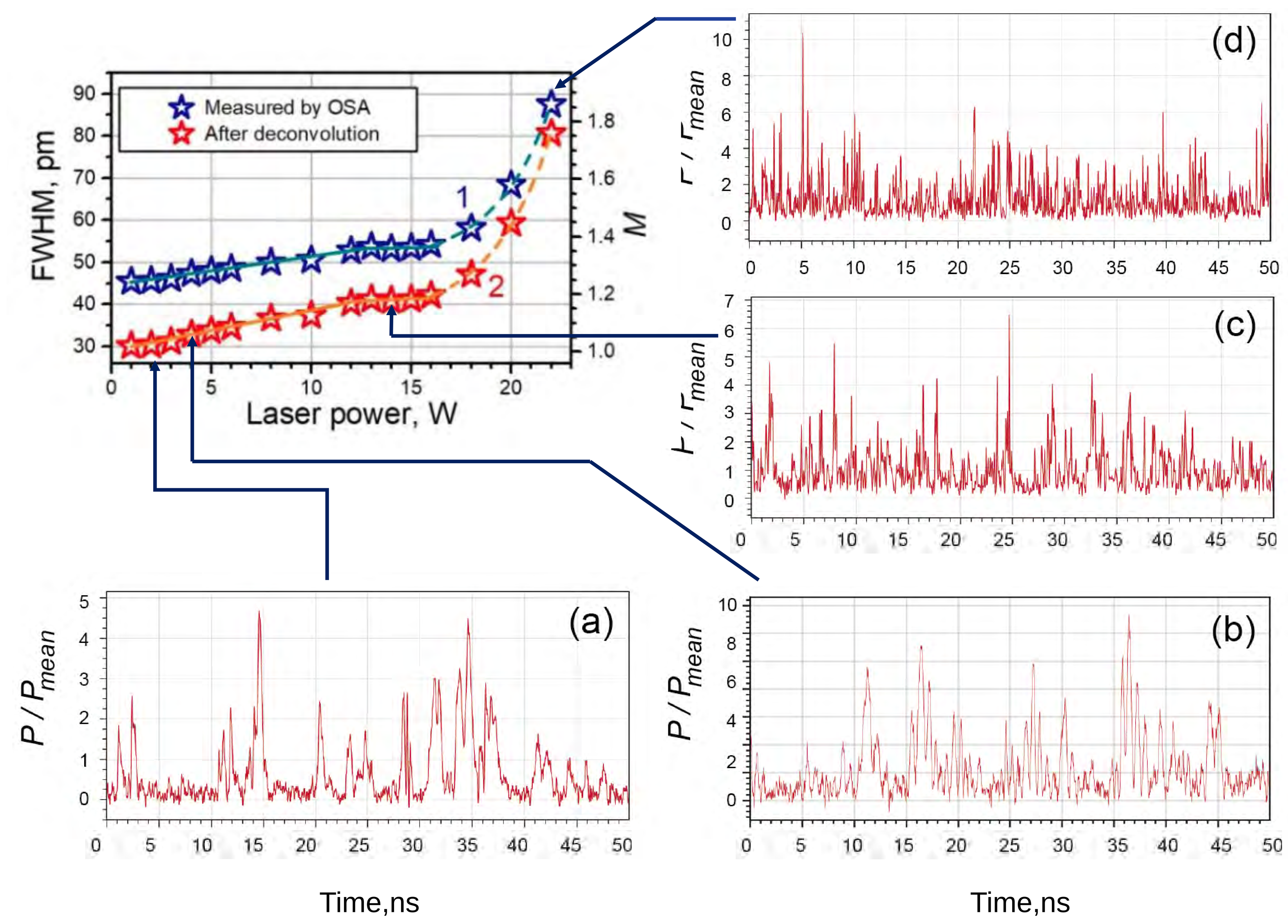
Power performance and detuned spectra are presented next.





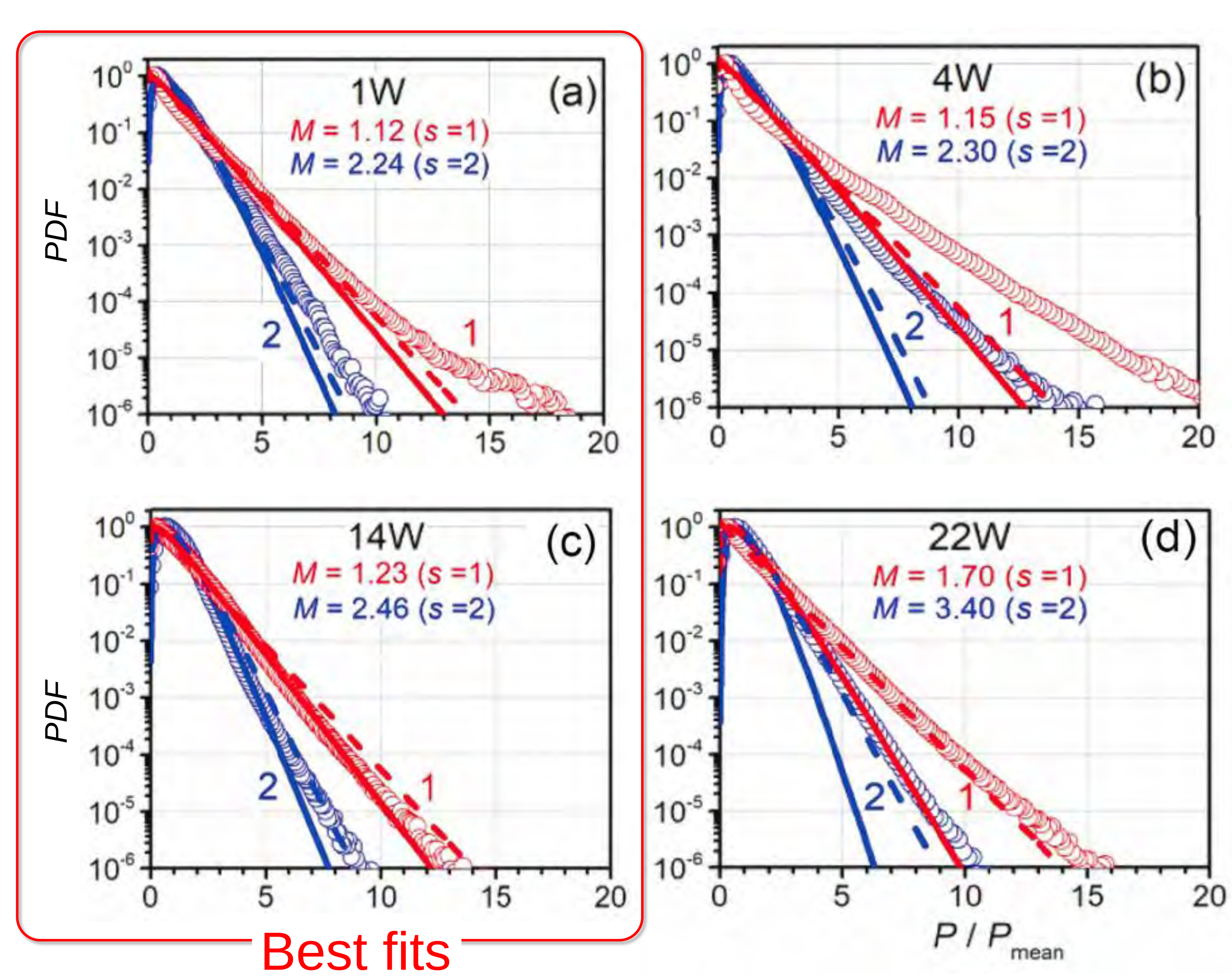
Measurements and Results

In next figure it can be seen that for 18 W and above, spectral widths tend to grow faster, also we can note that average width of the pulses in each train decreases significantly with power.



For 18 W, L_{NL}~ 4 m, almost 5 times less than cavity length, with n_2 = 4.3×10-20 m^2/W @ 1.06 μm and A_{eff} = 17 μm^2.

Experimental histograms (PDF) measured with polarizer (red circles) and without it (blue circles), theoretic BE models (solid lines) and ideal unitary case (dashed lines) are presented next:



Conclusions

We have demonstrated that narrow band YDFL operates in the regime of random noise pulses, not in true continuous wave (CW) or quasi-CW modes. The probability density functions are explicitly described by the M-fold degenerate Bose-Einstein distribution at low (~ 1 W) and 'intermediate' (~ 14 W) laser powers, thus indicating that the YDFL oscillates in the regime, statistically inherent to narrow-band thermal light. At higher laser powers, the photon statistics demonstrates longer tails than in the Bose-Einstein model; denoting much more frequent generation of high-energy pulses than that predicted by the classical theory of narrow band ASE noise.

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