Full characterization of a semiconductor laser beam by simultaneous capture of the near- and far-field

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INTRODUCTION

- We present a new measurement method for **fully characterizing** a laser beam, i.e. determining the optical phase as well as the intensity.
- The method is based on the **simultaneous capture** of the near- and far-field, making this method very suitable for laser beams with temporal variations in intensity and/or phase.
- A **single plano-convex lens** is used to create **equally large** images of the near- and far-field.
- **Anti-reflectance coatings** on the lens surfaces reduce the need for attenuating filters that disturb the phase, when measuring on high-power lasers.
- When the optical phase has been retrieved, the **M^2-value** can easily be determined by numerical propagation.

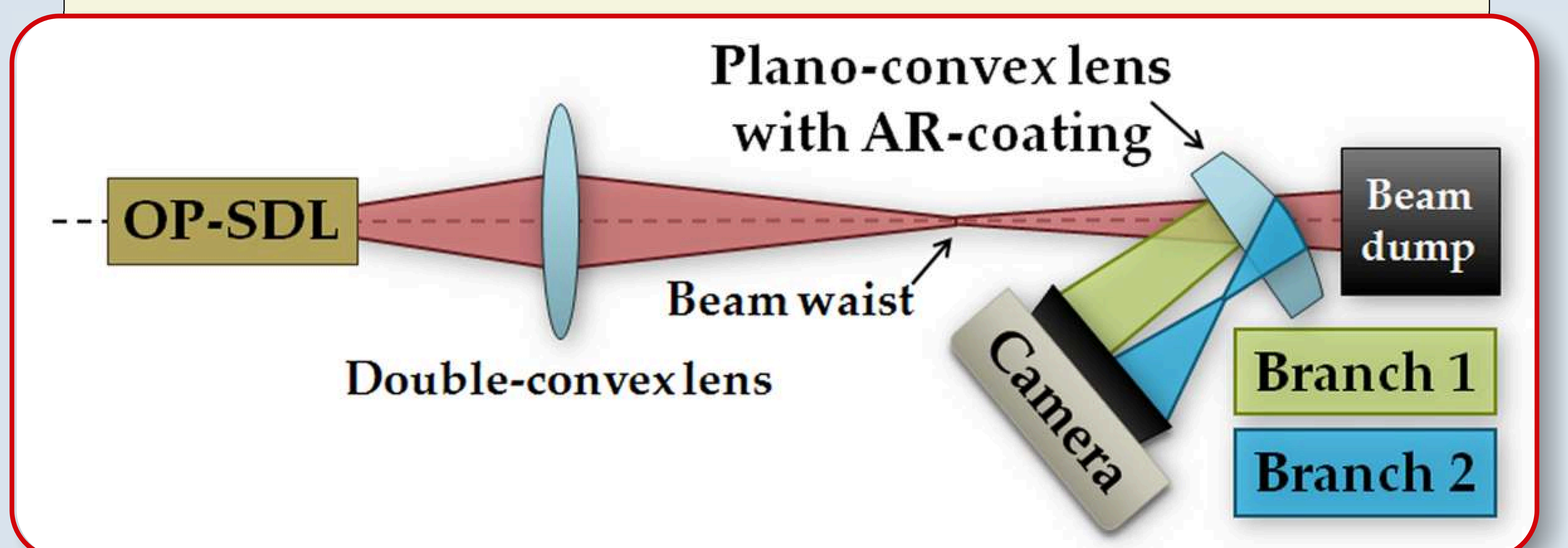

Fig. 1. A schematic view of the experimental setup. The near- and far-field images on the CCD camera are created by a single optical component: a plano-convex lens.

SETUP

- The main components in the experimental setup, see Fig. 1, are a **plano-convex lens** and a **CCD camera**.
- Light incident on the lens will be reflected both at the flat and at the curved surface of the lens, splitting the beam into **two branches**.
- **Branch 1**, created by the flat surface, will produce the **far-field** on the CCD camera, see Fig. 2.
- **Branch 2**, created by the curved surface, will produce a **magnified image of the near-field** on the CCD camera, see Fig. 2.
- When the CCD camera and the plano-convex lens are correctly aligned, the CCD camera will capture the intensity distributions of the near- and far-field.
- The capture will be **simultaneous**; the near- and far-field are part of the same beam and invariant to temporal variations.
- The fields can be made to fill **equally large** areas on the CCD camera, which makes the phase retrieval **more stable**.

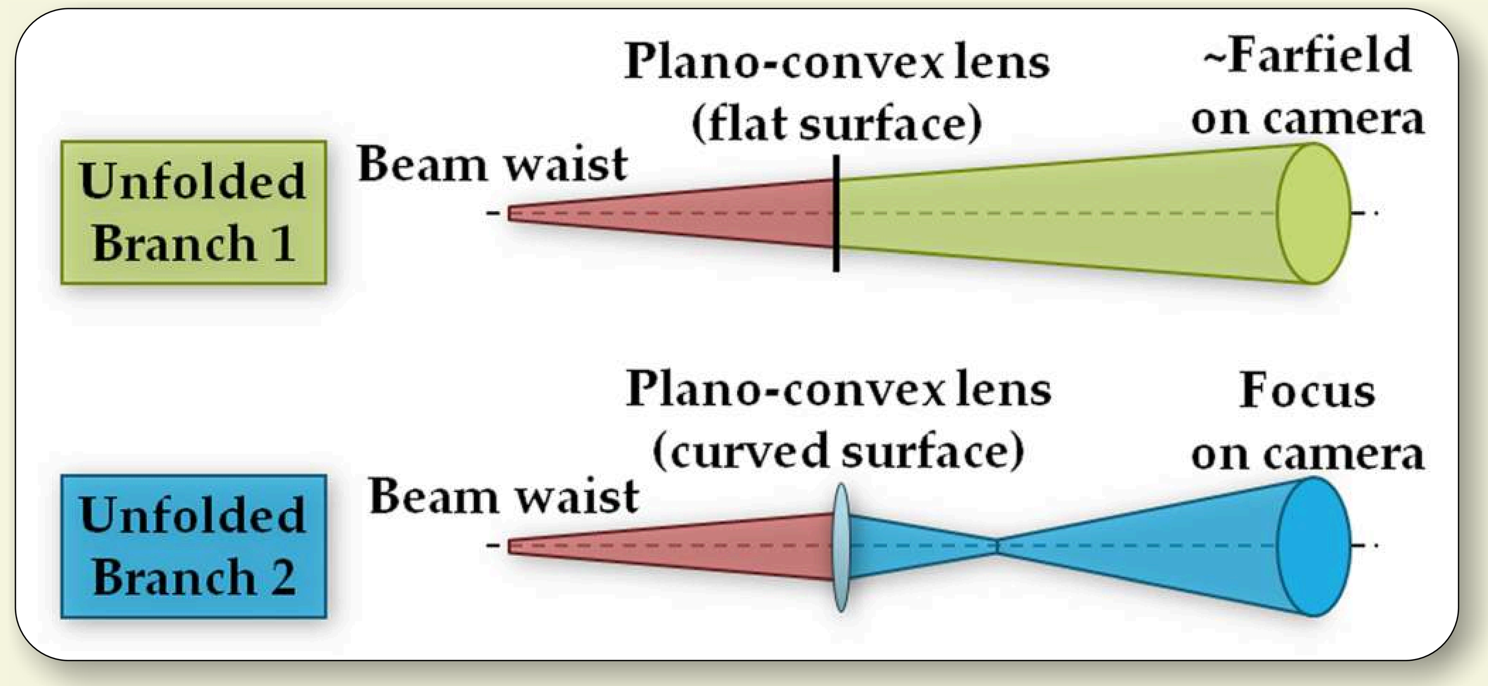

Fig. 2. The two optical branches in the setup, created by reflections at the flat and the curved surfaces of the plano-convex lens.

METHOD

- **Phase retrieval** is used to iteratively determine the phase distribution.
- A modified version of the **Gerchberg-Saxton algorithm** is used for the phase retrieval.
- The **two-step method** is used for numerical propagation of the optical fields, providing a free choice of sampling distance in the last plane common to both branches, i.e. just before the plano-convex lens.

RESULTS – TEM00 CASE

- Fig. 3 shows the results for a beam from an OP-SDL (optically pumped semiconductor disk laser) operating in **TEM00** mode.
- The retrieved intensity distributions **match** the measured distributions to a very high degree.
- The **M^2-value** was found to be **1.1** in both the x- & y-directions.

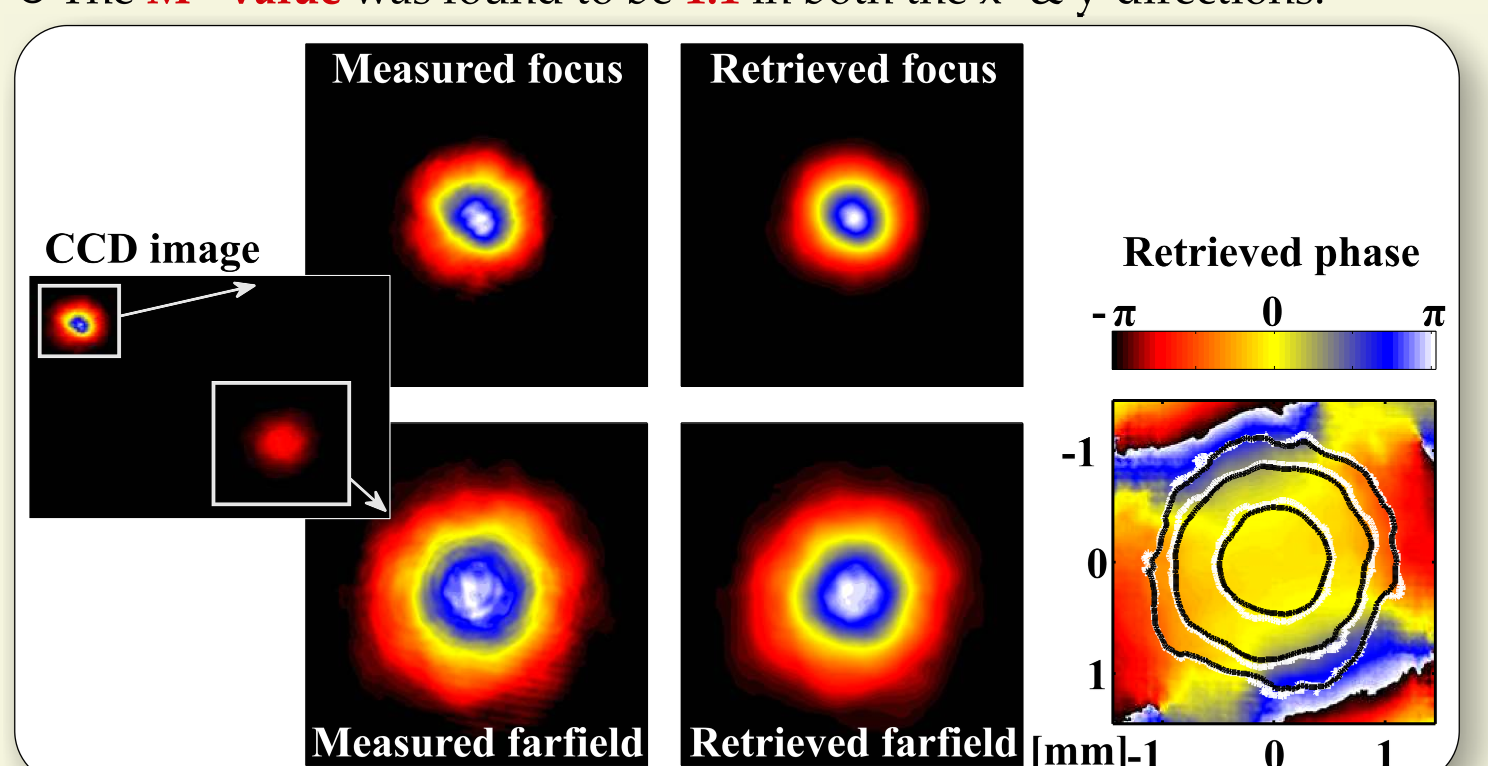

Fig. 3. Close match between the measured and retrieved intensity distributions of a TEM00 laser beam. The retrieved phase distribution is overlaid with intensity contours (50%, 10%, and 2% of peak).

RESULTS – TEM10 CASE

- The method can also handle **higher order modes** with rapid phase variations, for instance the TEM10 mode, see Fig. 4.
- The **M^2-value** was in this case found to be **3.3** in the x-direction and **1.3** in the y-direction.

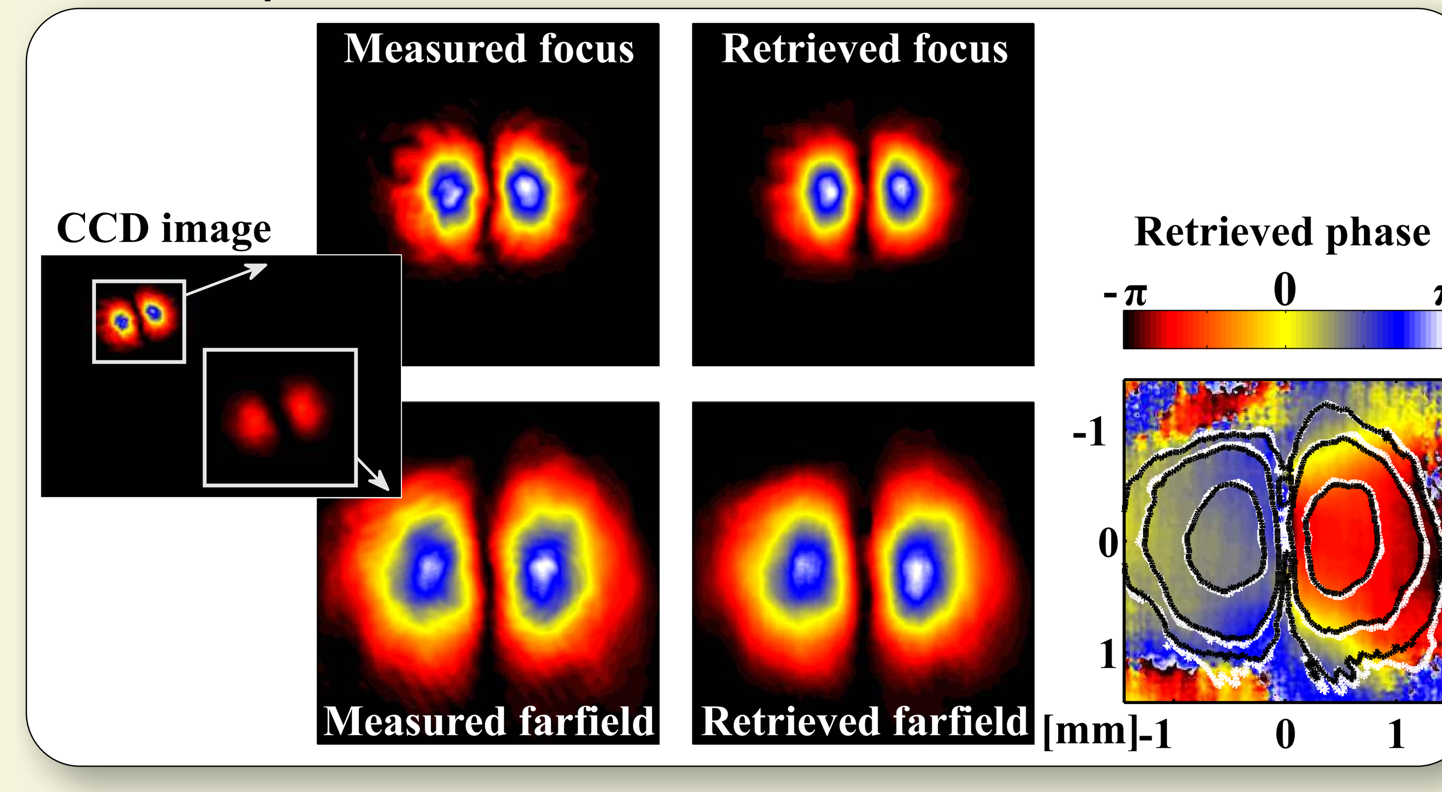

Fig. 4. The measured and retrieved intensity distributions for a TEM10 mode laser closely resemble each other. The retrieved phase distribution shows that rapid phase variations can be handled.

METHOD VALIDATION – INTRODUCTION OF KNOWN WAVEFRONT CURVATURE

- For validation, a **cylindrical lens** was inserted in the beam.
- The resulting phase distribution was **simulated** in MATLAB.
- The phase distribution was also **retrieved** through our method.
- The retrieved and simulated phase distributions show a **convincing agreement**, see Fig. 5.

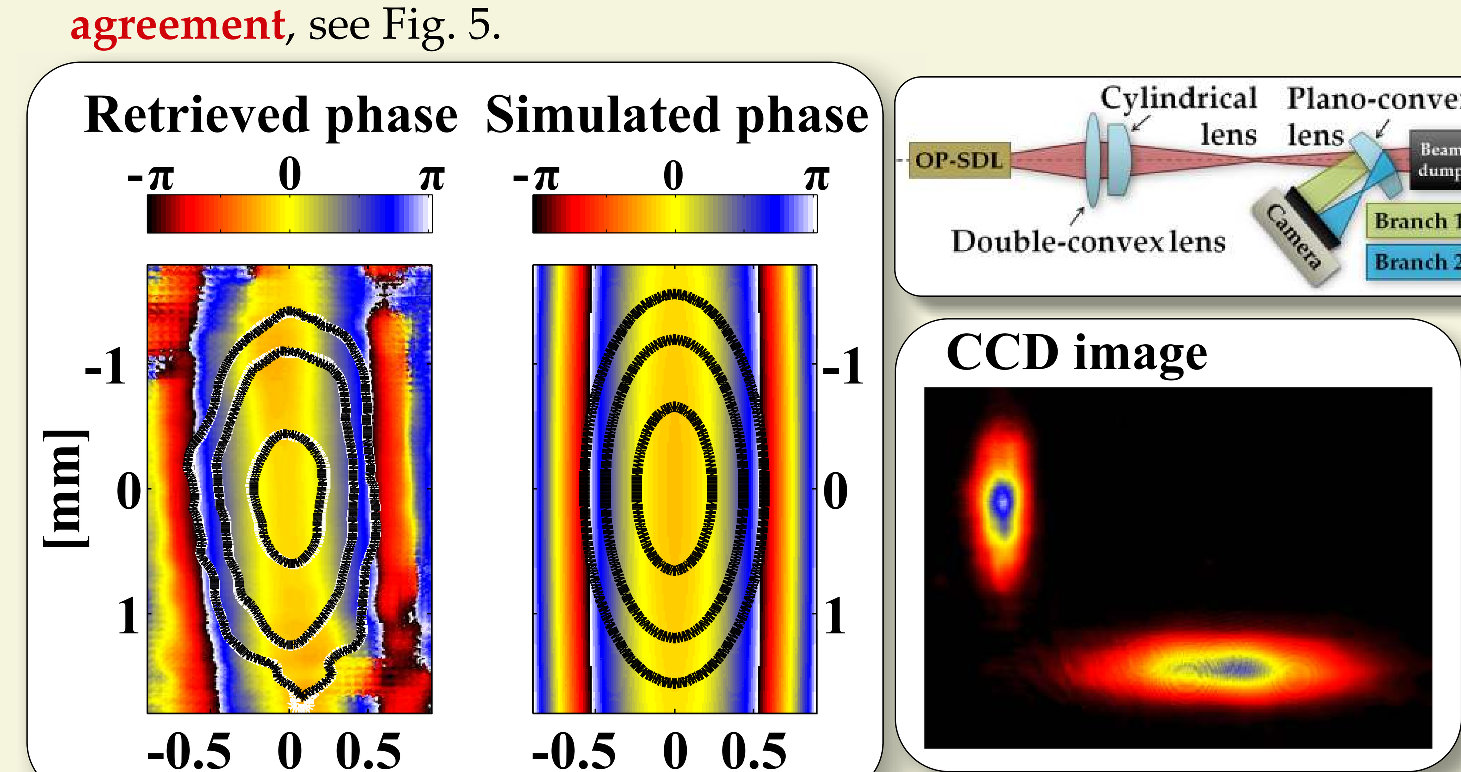

Fig. 5. The good match between the retrieved and simulated phase shows the accuracy of the phase retrieval in this method.