Equilibrium Modal Power Distribution Measurement of Step-index Hard Plastic Cladding and Graded-index Silica Multimode Fibers

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Standard far field angular power distribution generation

- 1) Long multimode fibre so that the modal power distribution reaches it equilibrium distribution
- 2) Mode filter formed by wrapping an optical fibre around a mandrel sufficient times to reach an equilibrium distribution
- 3) A commercial device designed to generate a standard near field Encircled Flux, EF, distribution

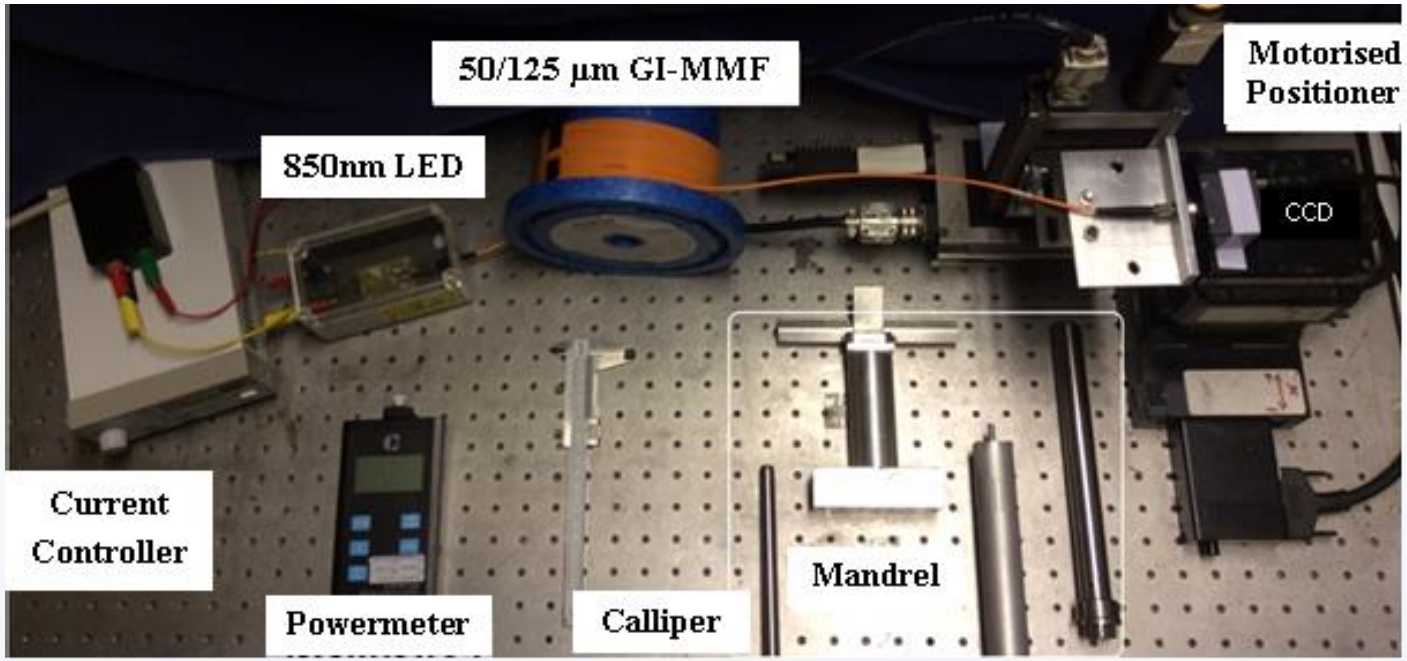
Encircled Angular Flux Measurement Techniques

- 1) The light from the source multimode fibre is allowed to diverge in free space onto a CCD camera chip placed in the far field.

  Far field: $d >> 2D^2/\lambda$, D-fiber core diameter

- 2) A commercial Fourier Transform or F-Theta lens system is used to convert the angular distribution into a spatial distribution which impinges onto a CCD camera chip. This is also referred to as the Far Field Pattern, FFP system.

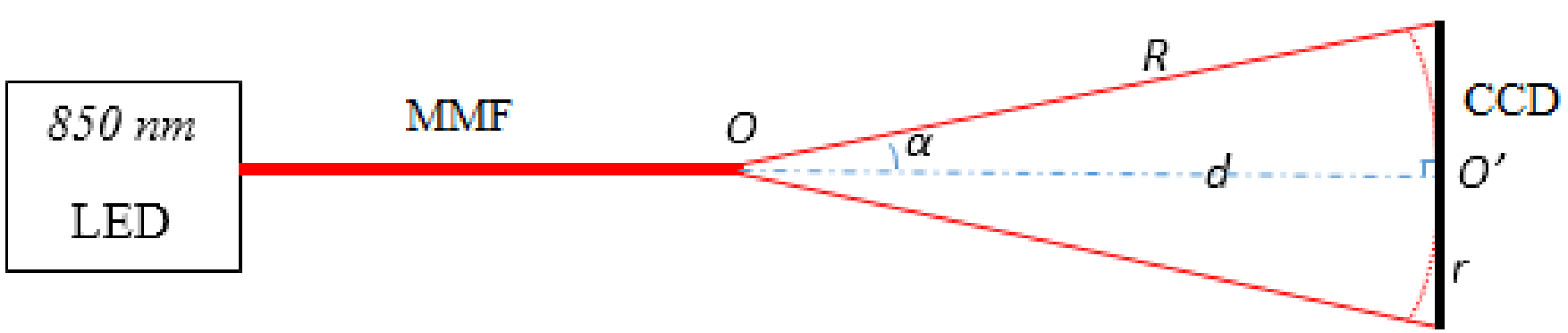
Experimental arrangement

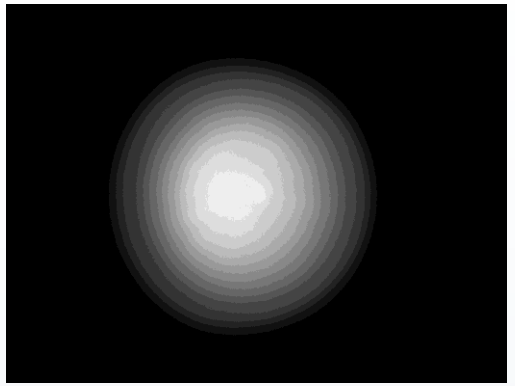


- LED1: HFE4050-014/FXA, controller: Thorlabs LDC202C
- LED2: Adamant FOLS-01
- *GI-MMF: 50/125 µm, 20 m*
- HPCF: OFS CF01493-10
- Adapter: Thorlabs SM1FC
- CCD: Prosilica EC1600

- LED1/LED2: *850 nm*
- 50 *µm* GI-MMF: Silica/Silica *NA=0.20 ± 0.02*, *d = 10 ± 1 mm,* $\alpha_{max} \sim 13°$
- 200 *µm* SI-MMF: HPCF *NA=0.37 ± 0.02* , *d = 105 ± 1 mm,* $\alpha_{max} \sim 26°$

Encircled Angular Flux

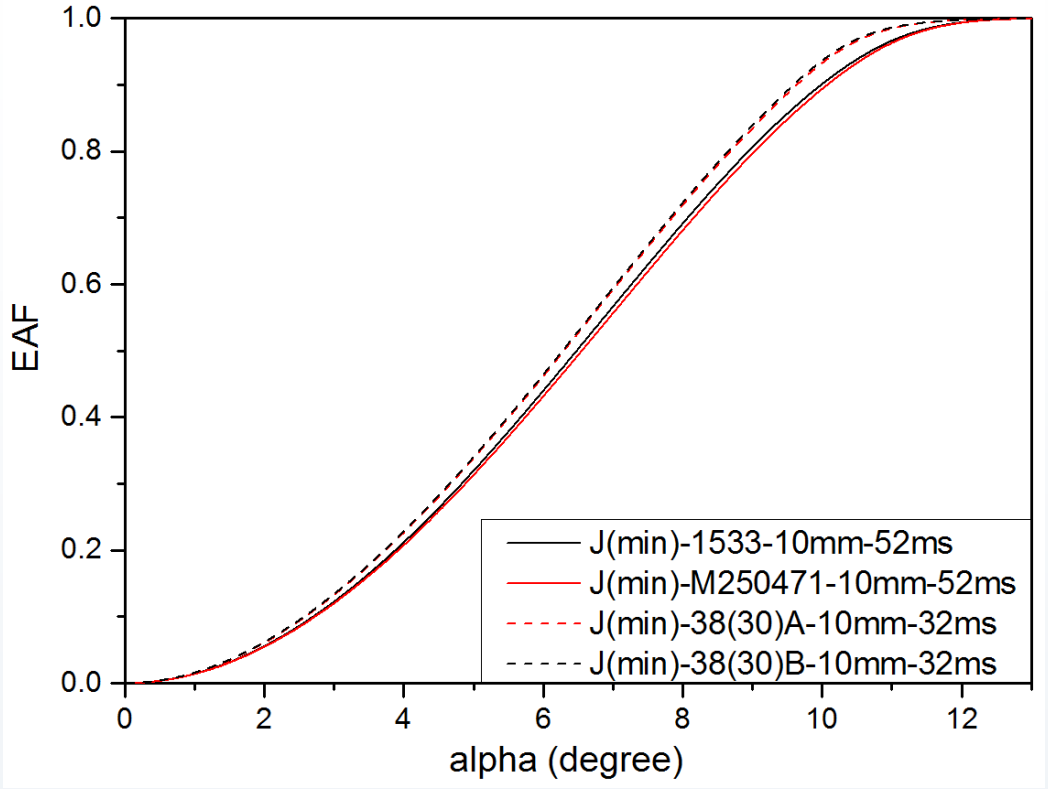




- Encircled angular flux (EAF): $\int P(\alpha)/P(\alpha_{max}) \cdot d\alpha$
- $tan(\alpha) = r/d$
- $\alpha_{max} >$ arcsin (NA)
- $\Delta\alpha$: *related to pixel size*
- O': centroid of far field image

EAF: Free space divergence onto CCD measurement method

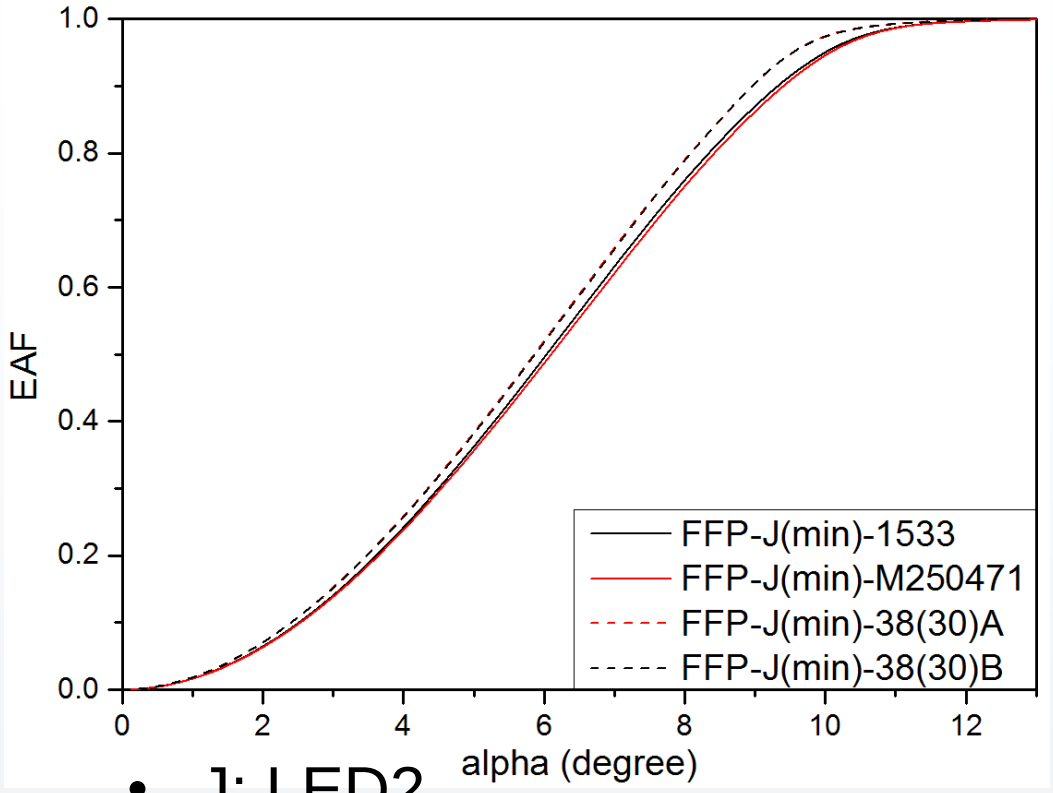
- Labelling convention example:
- J(min)-1533-10mm-52ms

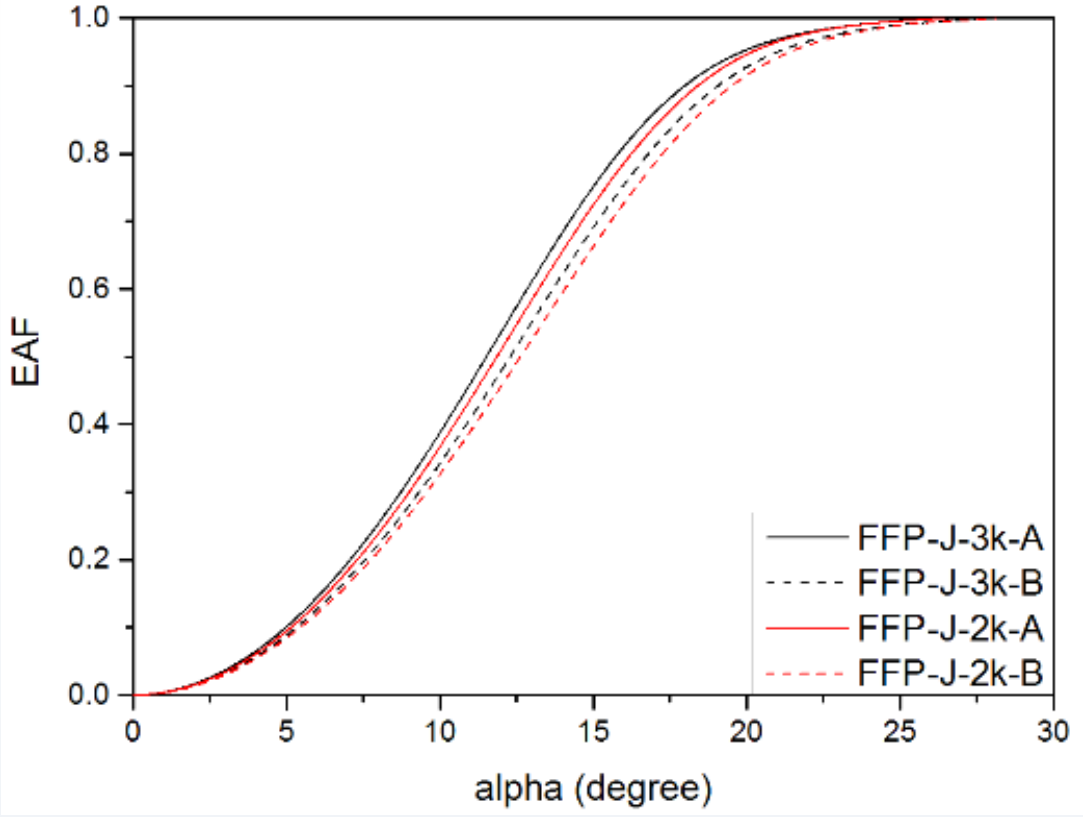


Label

- J(min): LED2 at minimum output
- 1533: “modcon” serial No., Modcon 1
- M250471: “modcon” serial No., Modcon 2
- ×× ms: exposure time of CCD
- 10 mm: the distance between fiber end and CCD
- 38(30): *38 mm* diameter Mandrel with *30* turns of *50 μm* GI-MMF
- A/B: side A or side B of the fiber under test connected to the LED

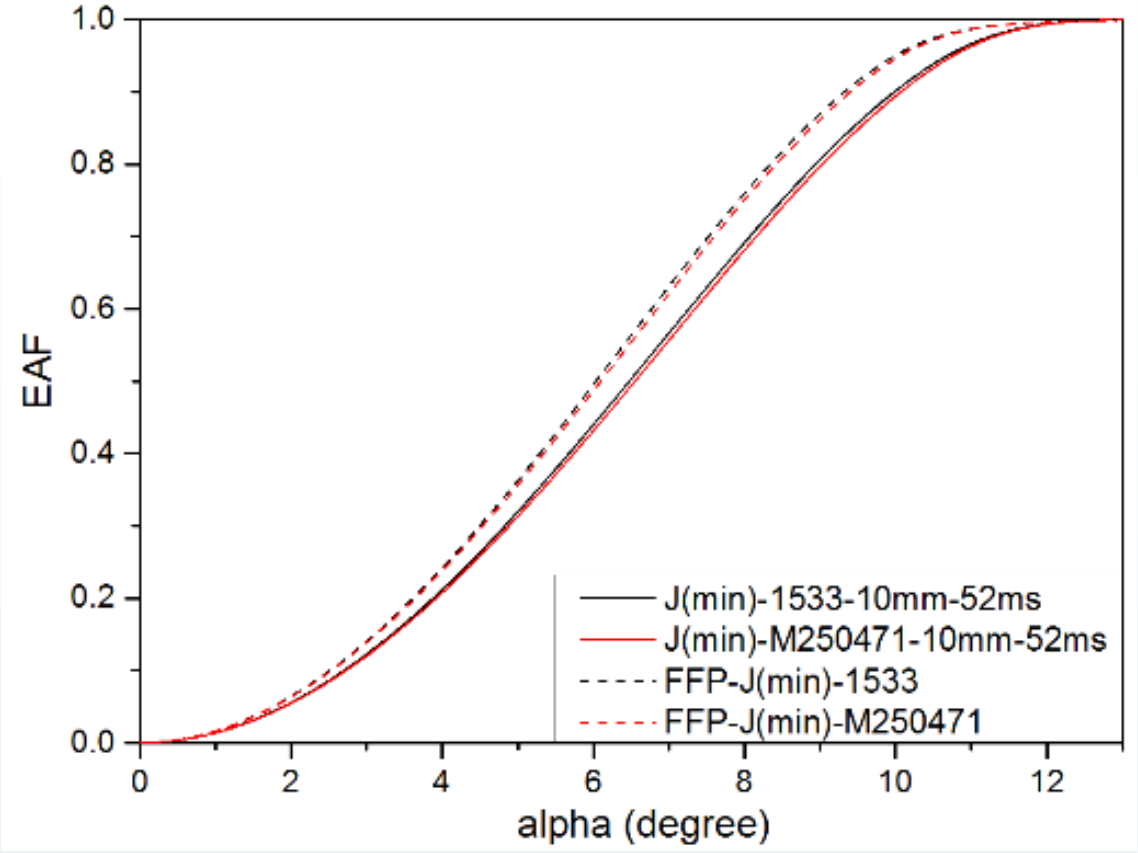
EAF: F-θ Lens measurement method

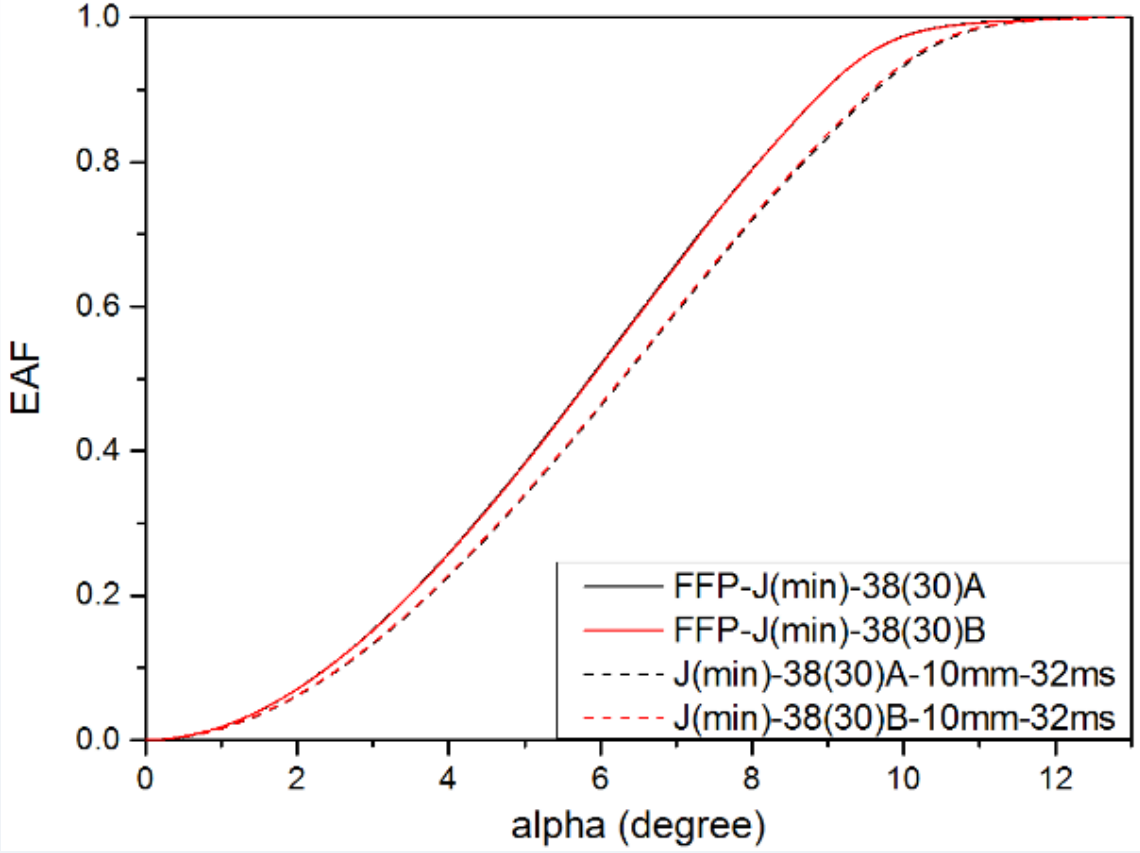




- J: LED2
- 1533: “modcon” serial No. ; M250471: “modcon” serial No.
- 38(30): *38 mm* diameter Mandrel with *30* turns of *50 μm* GI-MMF
- A/B: side A or side B of the fiber under test connected to the LED
- 2/3 k: 2 km or 3 km HPCF

EAF: Comparison of free space divergence and F-Theta lens measurement methods

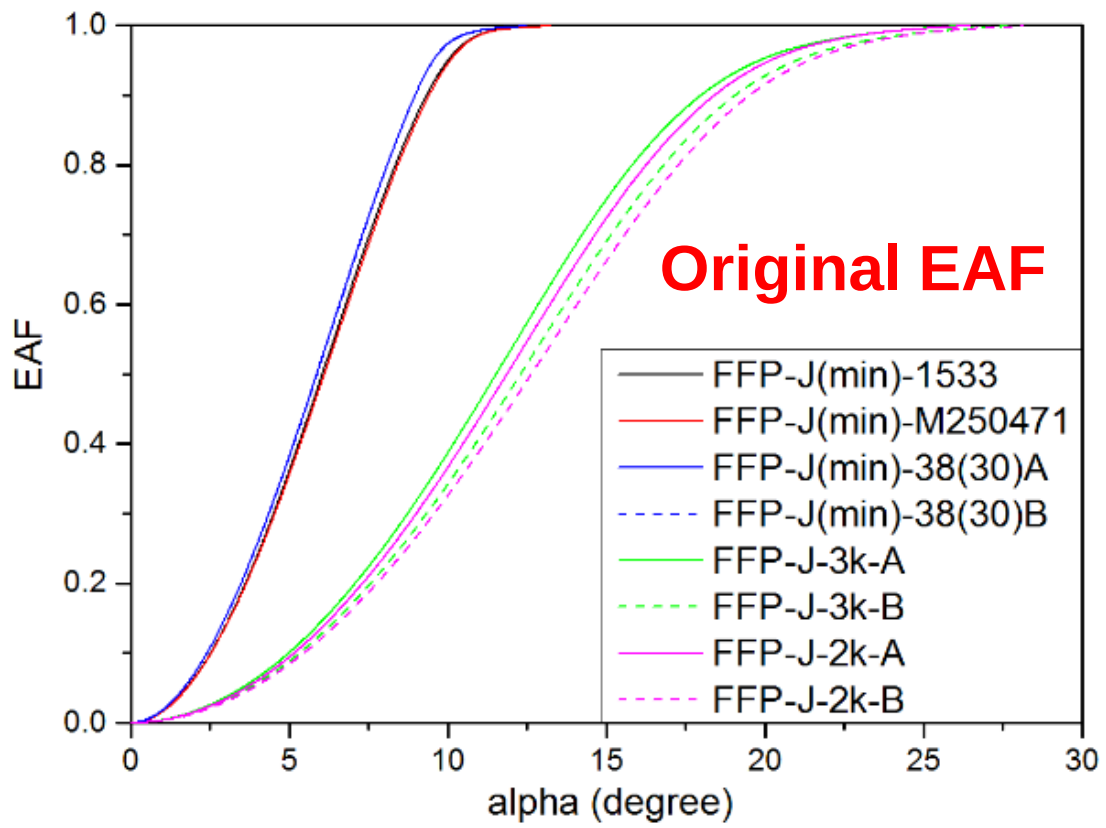


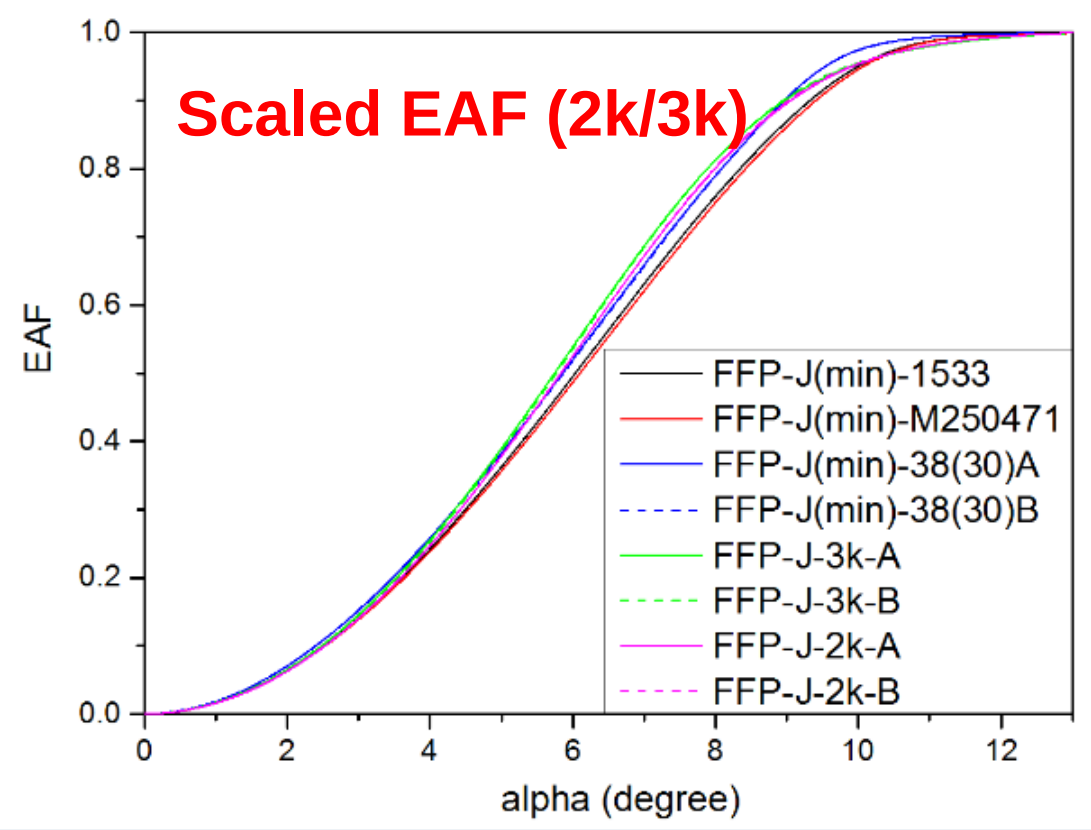


- (1)“Modcon”
- (2) Mandrel: 30 turns

EAF: compare three EMD methods

- "Modcon": 1533, M250471
- Mandrel: *38 mm* diameter, wrapped with *50 μm* GI-MMF
- Long fiber: 2 km, 3 km HPCF

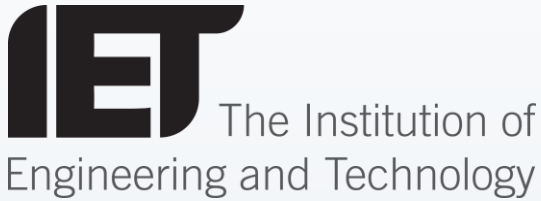




Conclusions

- 30 turns of a GI-MMF around a 38 mm diameter mandrel were found to be sufficient to reach an equilibrium mode distribution.
- The two different near field Encircled Flux “modcon” sources gave very similar EAFs to each other and to the wrapped mandrel source
- The free space divergence measurement method gave similar but not exactly the same results for EAF as the F-θ lens method. Some further research is needed to bring them into closer agreement.
- At least *3 km* of HPCF is required to reach an equilibrium mode distribution
- A new method of scaling the angle by the maximum angle brings all of the curves very close together so that a single standard EAF curve can be defined as long as the scaling factor is stated.

Acknowledgements



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