DMD simulations based on scaled/non-scaled index profiles and comparison with Cambridge model results

Gary Shaulov

RSoft Design Group

gary@rsoftdesign.com

Yu Sun

Optium

ysun@optiumcorp.com

IEEE 802.3aq 10GBASE-LRM Interim Meeting,
Ottawa, September 2004

Introduction

❑ In previous Task Force meetings we presented simulation results comparison between in-house/commercial simulators and Cambridge model (Long Beach, Optium/Broadcom, *sun_1_0504.pdf* and Portland, RSoft, *shaulov_1_0704.pdf*).

❑ Here we present results of comparison for DMD simulations for scaled and non-scaled index profiles from 81-fiber set by using RSoft commercial simulator (*ModeSYS™*) and Optium in-house simulator on one side and Cambridge model on the other side.

❑ The objective was to benchmark our simulators against Cambridge results and if agreement is good then we may be confident in using our simulation tools for further task-related studies such as launch conditions, connector offsets, time-varying effects, etc.

Outline

- Comparison of results out of Optium in-house and RSoft simulators, in particular pulse shapes of fiber output signal

- Derived pulse shapes compared with the ones in Cambridge model for selected fibers

- DMD simulations by RSoft for non-scaled and scaled index profiles and comparison with Cambridge/Corning results

- Discussion of results discrepancies between RSoft/Optium and Cambridge

- Second iteration of DMD simulation with studying the effect of number of mode groups included in simulations

- Comparison of new results with Cambridge/Corning

- Summary

Comparison of RSoft and Optium in-house simulators

Pulse shapes of output from multimode fibers were studied
for new scaled Cambridge index profiles

Parameters:

1. Input beam: Gaussian with 7 µm FWHM
2. Input pulse: Gaussian with 50 ps FWHM
3. Wavelength: 1300 nm
4. Fiber interested: Cambridge #23, #29 and #36 *
5. Offset considered: 17, 20 and 23 µm
6. Fiber length: 300m

Note : Fiber numbers 23, 29, and 36 out of new 81-fiber sets correspond
to fiber numbers 18, 24, and 31, respectively in 65-fiber set of Cambridge
model release 1.0.

Comparison of pulse shapes: Optium vs Rsoft

Blue curves: Optium
Red curves: RSoft

Fiber # 29, offset 17 μm

Fiber # 23, offset 17 μm
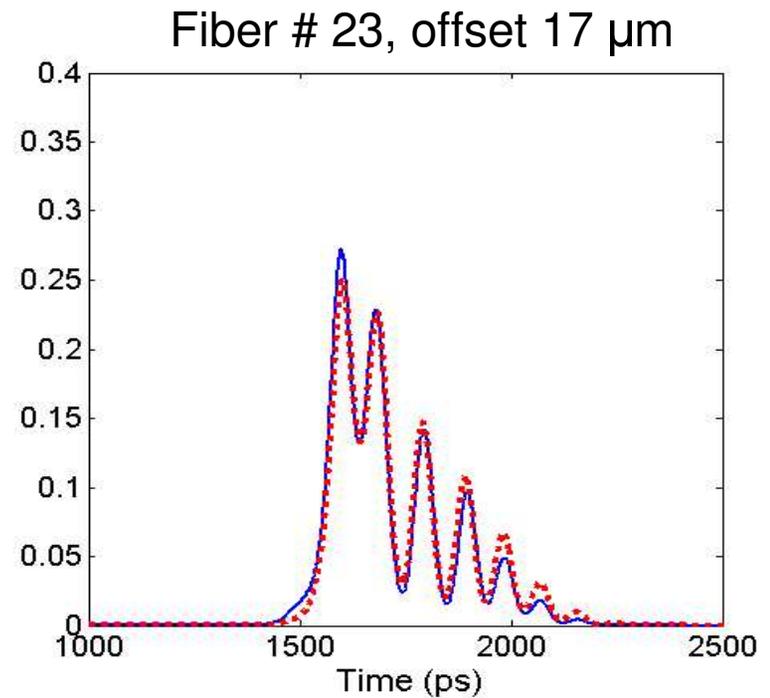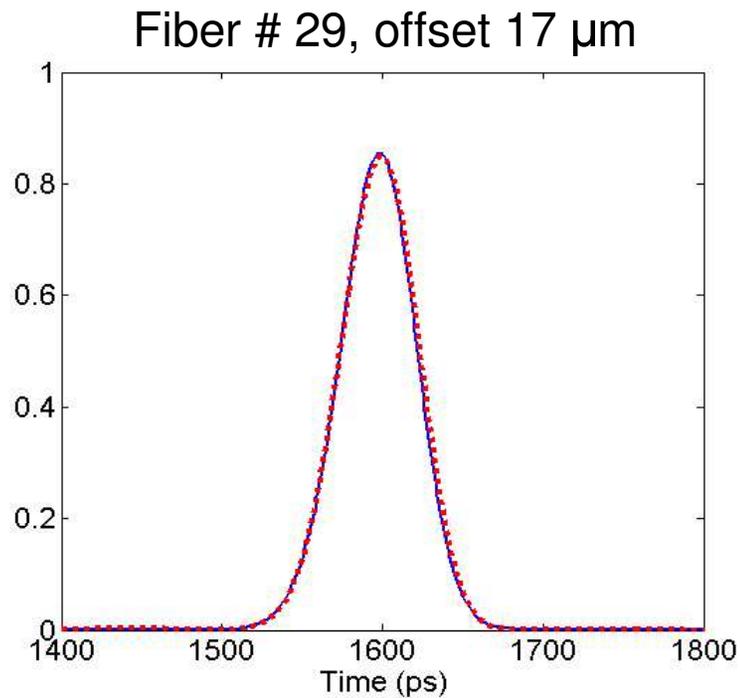
Very good agreement for both fibers, same also for other offset values

Comparison of pulse shapes: Optium vs Cambridge

Blue curves: Optium
Red curves: Cambridge

Fiber #29
Offset 17 μm

Fiber #23
Offset 17 μm
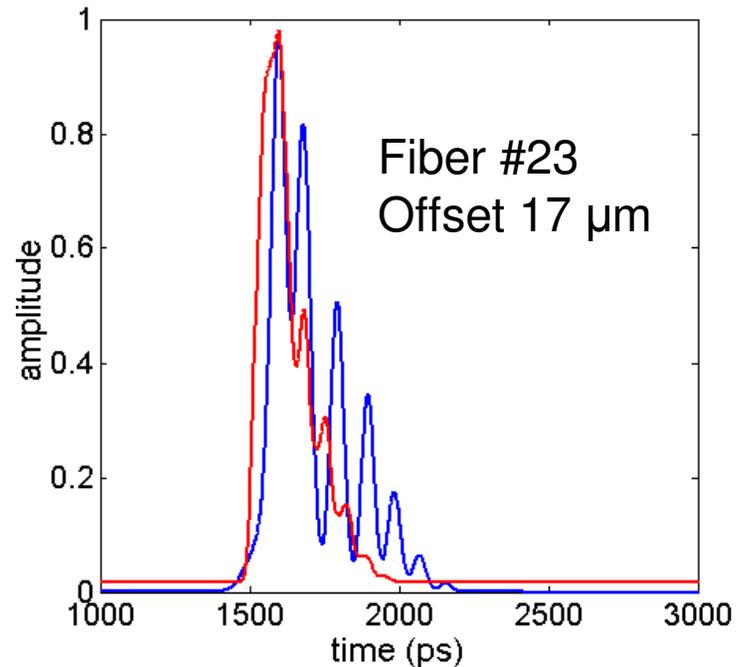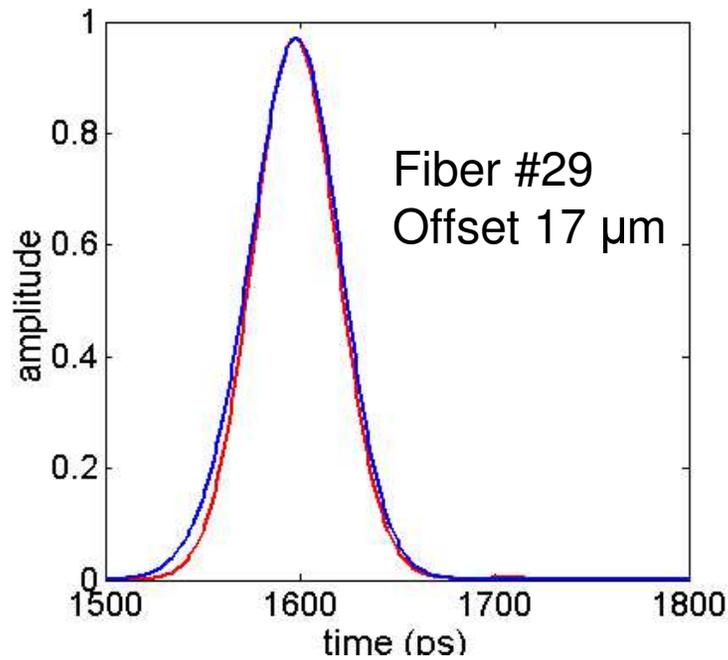
Good agreement for fiber #29 but not so good for fiber #23

DMD study for scaled and non-scaled index profiles – comparison of RSoft and Cambridge results – first iteration

- Three fiber index profiles were studied - fibers 23, 29, and 36 (according to latest Cambridge release) – first non-scaled and then scaled profiles.
- Fiber #23 has only alpha change, #29 – also sudden edge defect, and #36 – also center peak and exponential edge defect
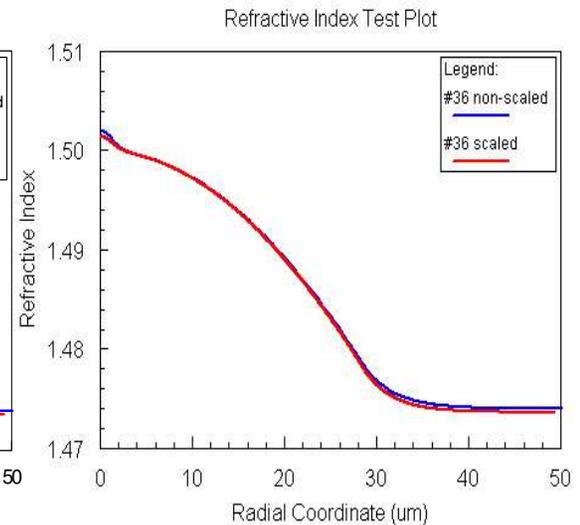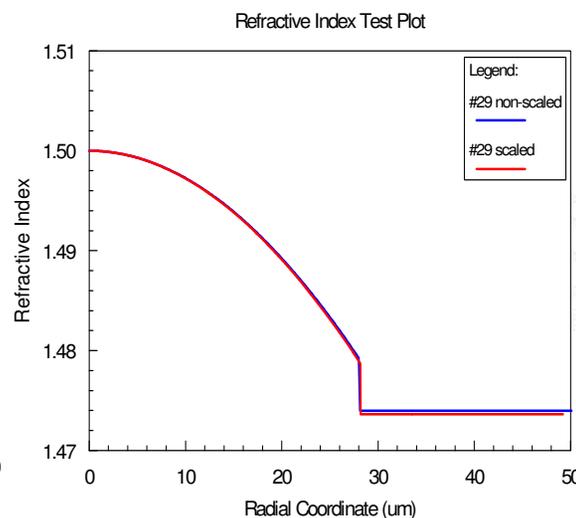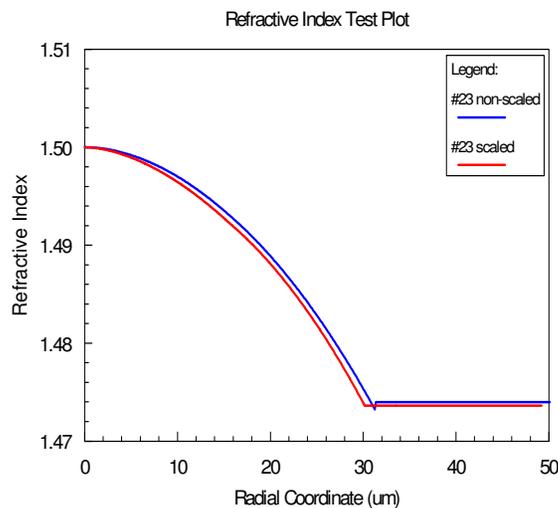
Fiber # 23 – first iteration
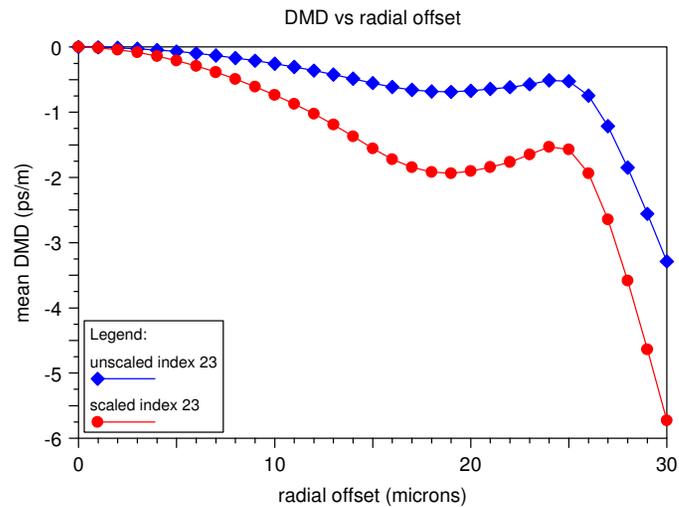
DMD scaling factor according to:
   Cambridge model : f = 2.7054
    RSoft simulation :   f = 0.767
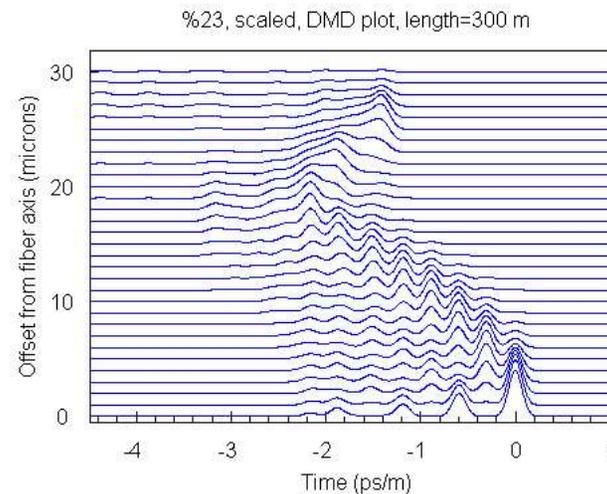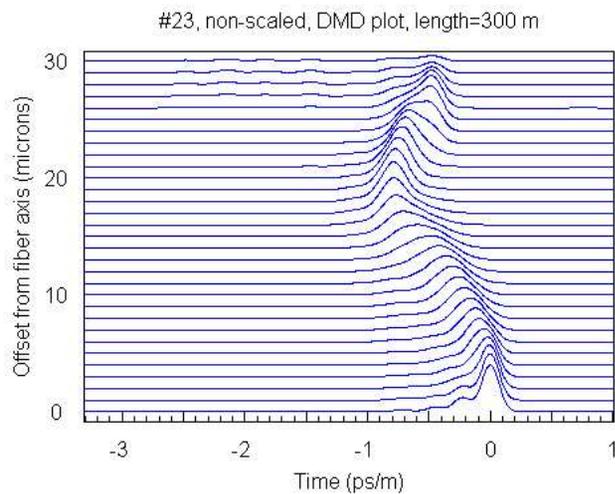
Fiber # 29 – first iteration

DMD vs radial offset

Legend:
unscaled index 29
scaled index 29

mean DMD (ps/m) vs radial offset (microns)
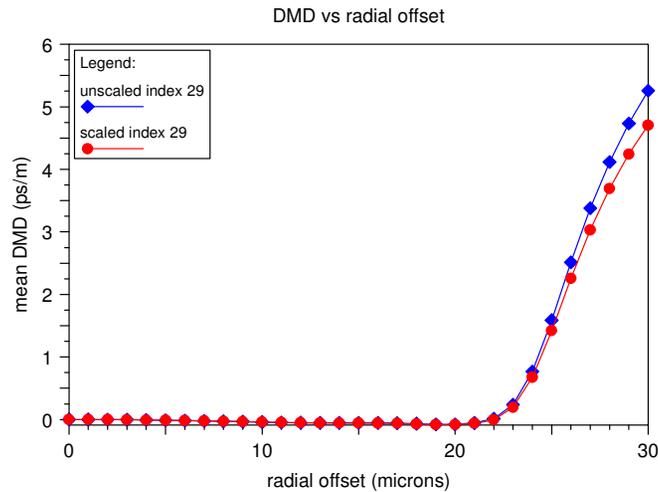
DMD scaling factor according to:

Cambridge model : f = 0.8424

RSoft simulation : f = 0.354

#29,non-scaled, DMD plot, length=300 m

Offset from fiber axis (microns) vs Time (ps/m)

#29, scaled, DMD plot, length=300 m

Offset from fiber axis (microns) vs Time (ps/m)
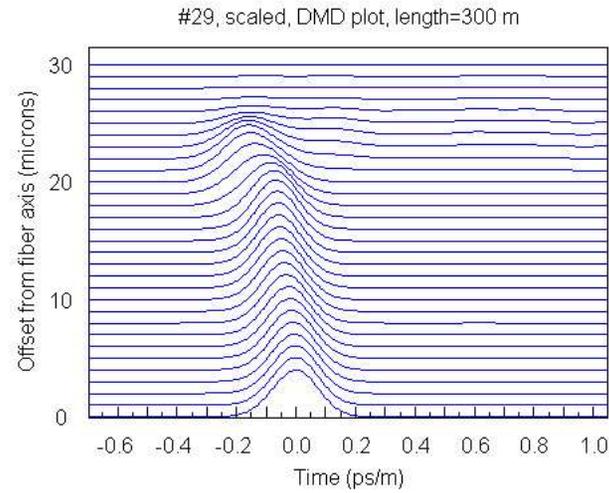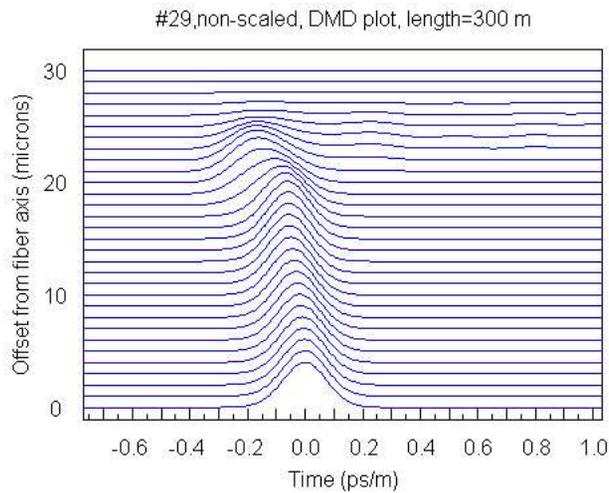
DMD results comparison – first iteration

RSoft (non-scaled DMD)

DMD vs radial offset - Fiber 23

DMD vs radial offset - Fiber 29
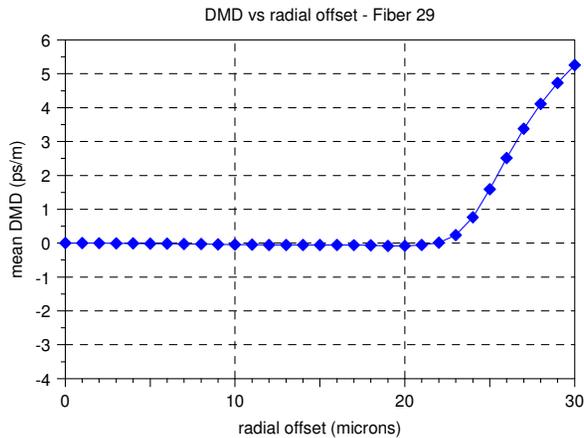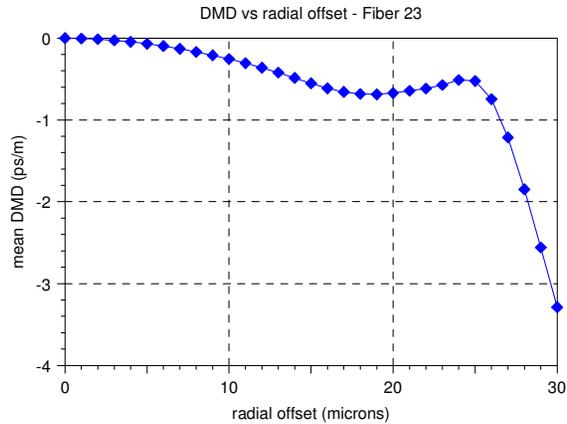
Corning/Cambridge (scaled DMD) *

18

DMD centroid

24
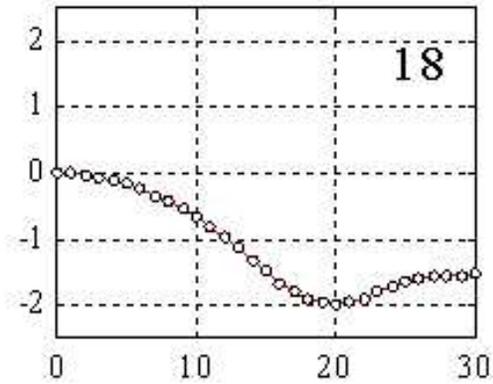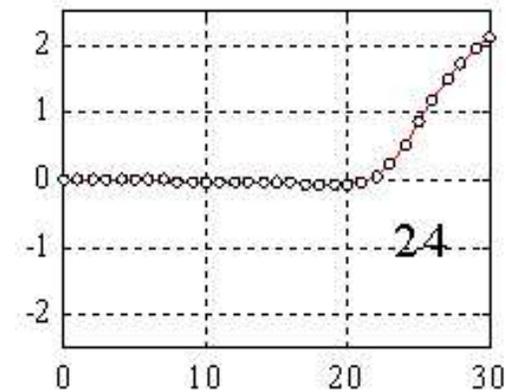
* See John Abbott's presentation at telecon 7/28/2004

Preliminary Conclusions

- The agreement between RSoft and Optium in-house simulators is excellent.

- Both RSoft and Optium results for pulse shapes are in good agreement with Cambridge results for fiber #29, however for fiber #23 the agreement is not as good.

- DMD simulations by RSoft for non-scaled/scaled index profiles showed good agreement with Cambridge results qualitatively except the high offset values (> 23 um), but not a good quantitative agreement.

- The difference may be due to the fact that the Cambridge model takes into account only first 18 mode groups. RSoft/Optium mode solvers based on solving for individual modes, not mode groups, and can in result include higher mode groups as well.

- To match Cambridge results RSoft/Optium simulations have to be repeated with the number of mode groups controlled.

Fiber # 23 – second iteration, with 18 mode groups

- Plot on the left shows DMD for different number of mode groups included.
- At 18 mode groups the scaling factor is
  - RSoft   **f = 2.7944**
  - Cambridge **f = 2.7054**
- Plot on the right shows DMD for non- and scaled indexes (for 18 groups)
- DMD of scaled index profile is 1.66 ns/km, nonscaled – 0.72 ns/km (factor 2.53)

DMD vs # of groups

Legend:
groups=18
groups=19
groups=20
groups=21

mean DMD (ps/m)

radial offset (microns)

DMD for fiber # 23 with and w/o scaling

Legend:
non-scaled
scaled

mean DMD (ps/m)

radial offset (microns)

RSOFT Design Group

Optium
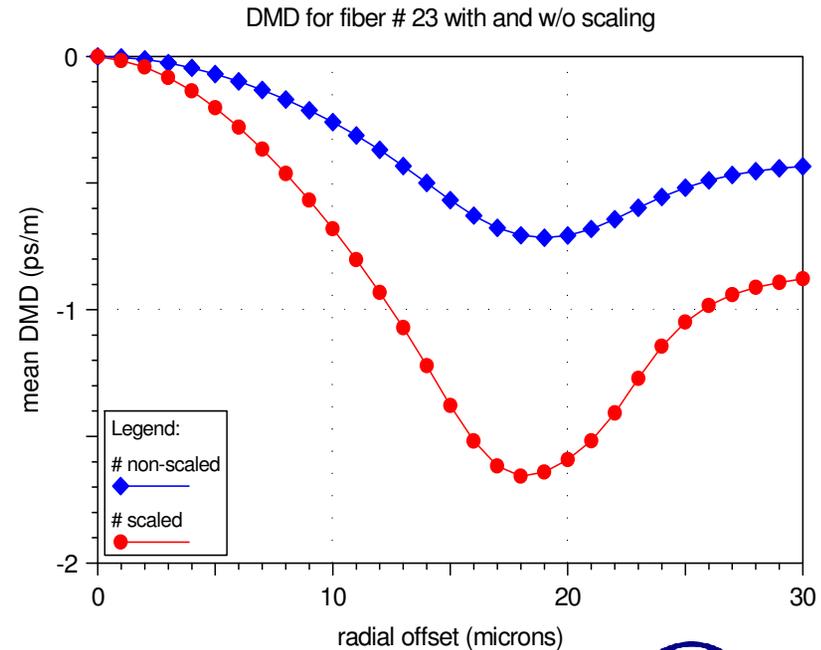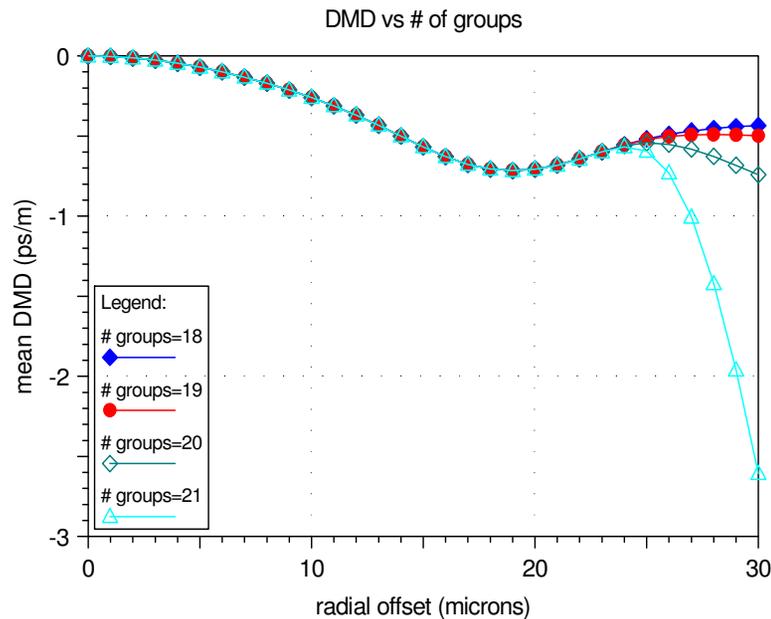
Fiber # 29 – second iteration, with 18 mode groups

- Plot on the left shows DMD for different number of mode groups included.
- At 18 mode groups the scaling factor is
  - RSoft   *f = 0.842*
  - Cambridge *f = 0.779*
- Plot on the right shows DMD for non- and scaled indexes (for 18 groups)
- DMD of scaled index profile is 2.18 ns/km, nonscaled – 2.57 ns/km (factor 0.85)
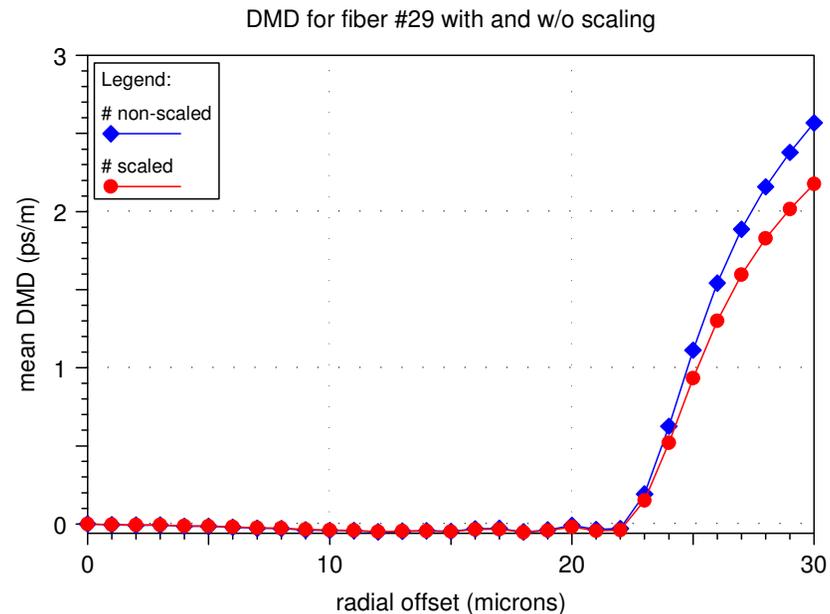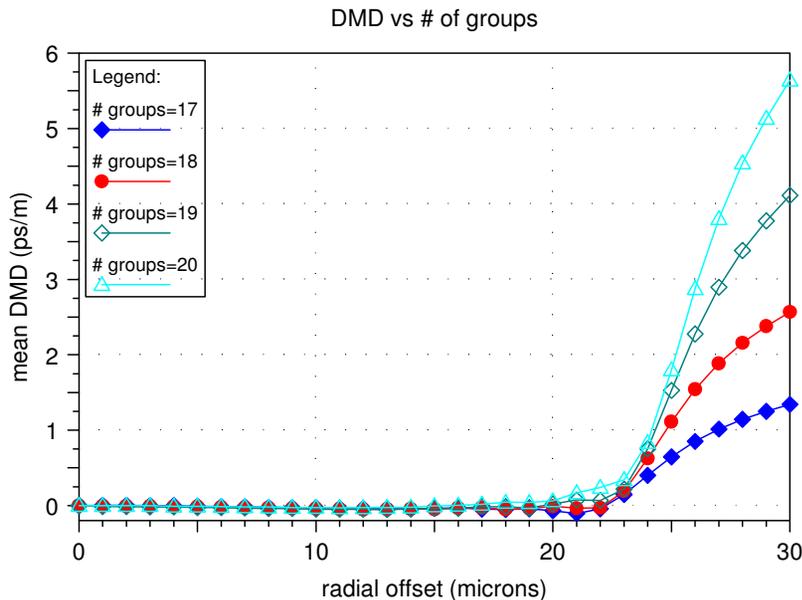
Fiber # 36

- Plot on the left shows DMD for different number of mode groups included.
- At 18 mode groups the scaling factor is
  - RSoft   **f = 0.7601**
  - Cambridge **f = 0.7248**
- Plot on the right shows DMD for non- and scaled indexes (for 18 groups)
- DMD of scaled index profile is 1.88 ns/km, nonscaled – 2.63 ns/km (factor 0.716)


DMD vs # of groups

DMD for fiber #36 with and w/o scaling
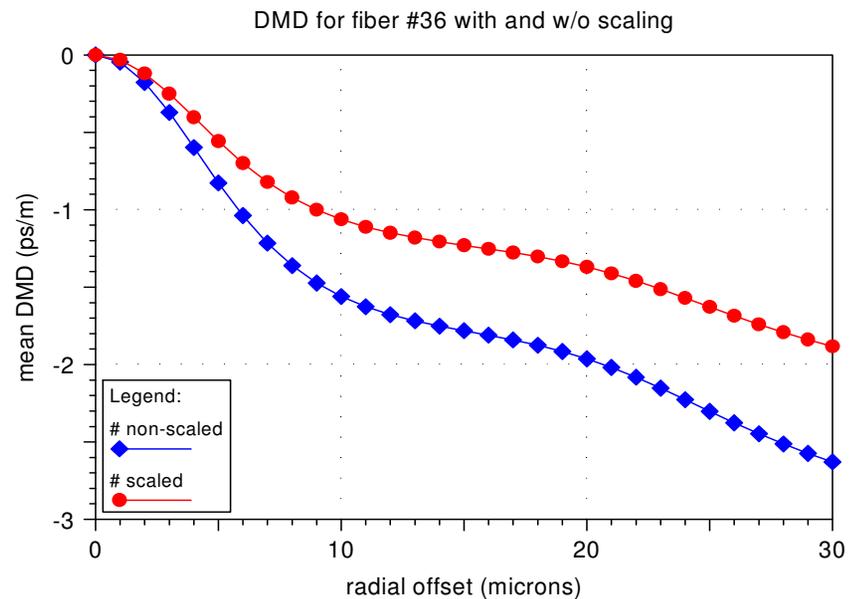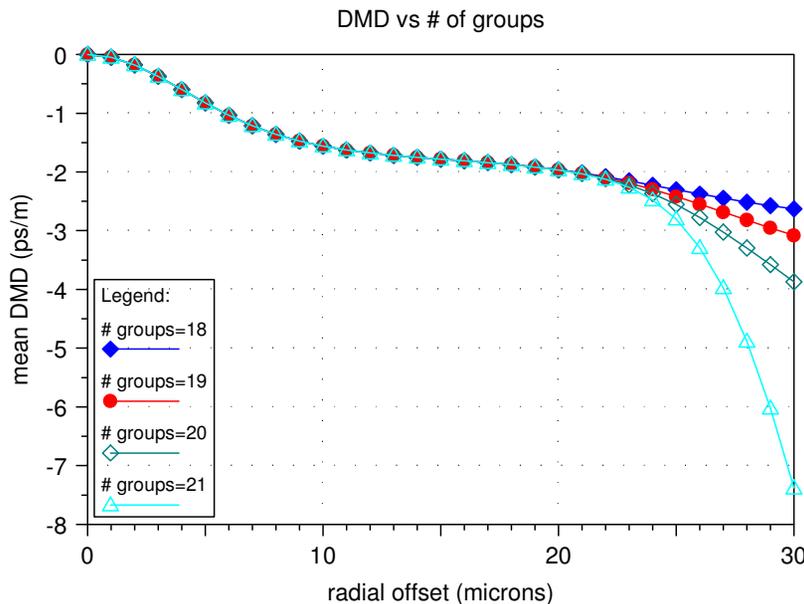
DMD Comparison – RSoft and Corning/Cambridge results

DMD for 3 selected fibers computed by RSoft simulator – top plots,
and Cambridge model (John Abbott, Corning, 7-28-04) – bottom plots.

DMD for fiber #23 with index scaling

DMD for fiber #29 with index scaling

DMD for fiber #36 with index scaling
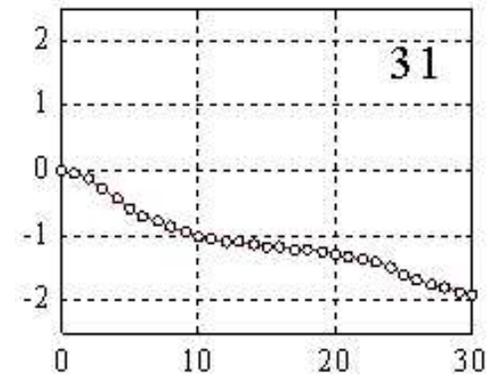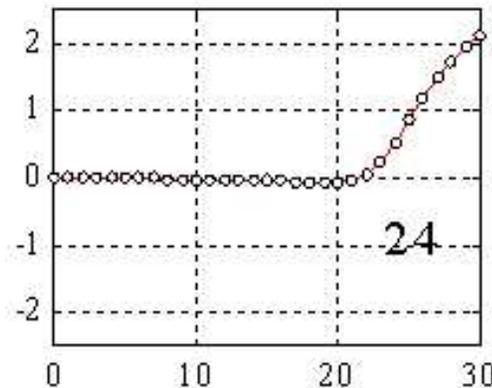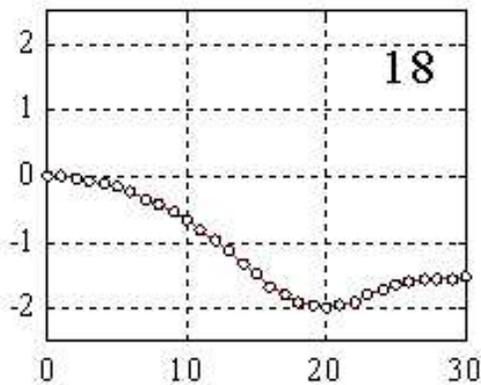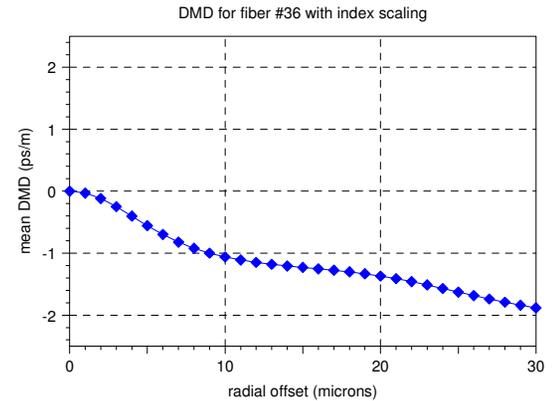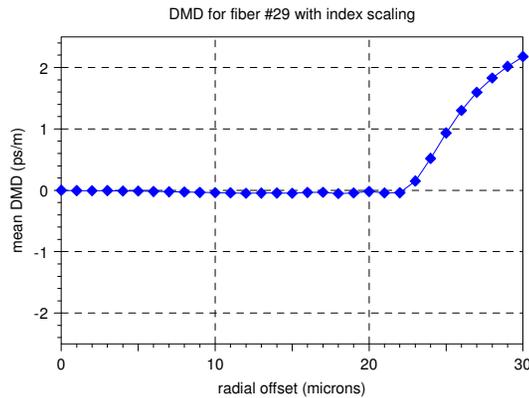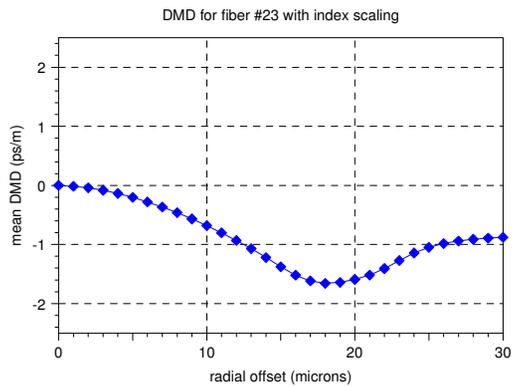
Summary

❑ We showed that DMD simulation results are sensitive to the total number of mode groups included in the simulation. That is especially true at high radial offsets, and the fiber's total DMD can change significantly if the number of mode groups are modified by even ±1. The cutoff number of 18 for number of mode groups in the Cambridge model must have a firm basis behind it to give confidence in the model approach.

❑ RSoft simulations for 3 different fiber models from 81-fiber set with the number of mode groups reduced to 18 gave very good agreement with Cambridge model – both for non-scaled index profiles (scaling factors are within 3-5% errors) and for scaled index profiles.

❑ Finally, the overall good agreement between RSoft/Optium and Cambridge simulations will stimulate us to go on with further simulation studies of various task of interest for 802.3aq group.