Statistics of Chromatic Dispersion Parameters

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Supporters

- Chris Cole
- Roberto Rodes
- Earl Parsons
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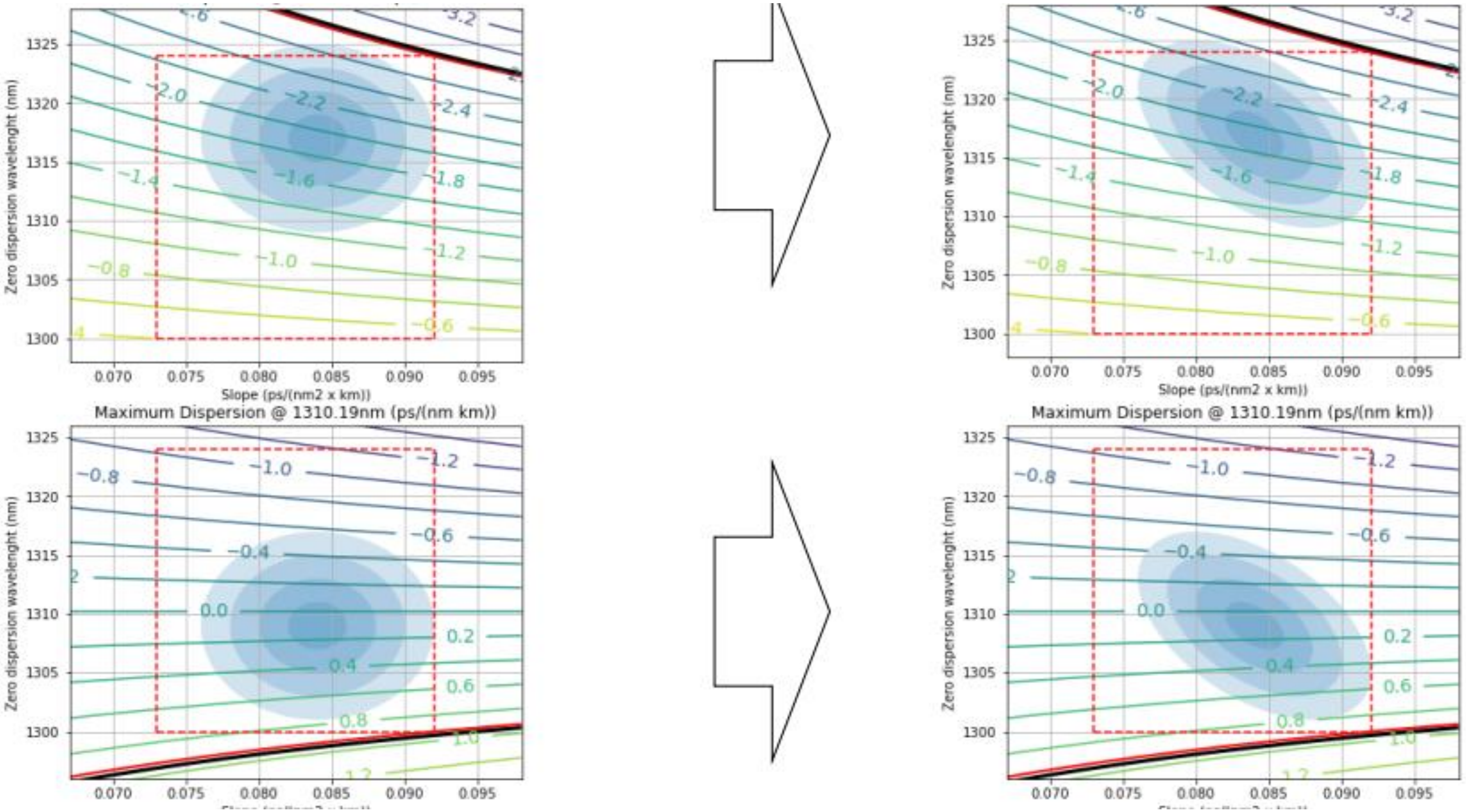
Background

- The zero dispersion wavelength (ZDW) and dispersion Slope (So), have been modeled as bivariate normal distribution with mean and standard deviations values described in Cole_3dj_optx_01_230427, liu_3dj_01a_2307, and johnson_3dj_2307.
  - Initial models assume uncorrelated ZDW and So.
- Fiber dispersion modeling shown in castro_3dj_optx_01_240222 indicates that for a given fiber design, the random perturbation on the fiber produce negative correlations between ZDW and So.
- The impact of correlation on models assuming a degree of negative correlation was estimated in rodes_3dj_optx_01a_240222 , assuming a correlation coefficient, (ρ) of -0.5.
- Here we propose a modification of the model based on separating systematic parameters related to the fiber design (which depends on the manufacturer) from the natural randomness occurring during manufacturing.

Impact of ZDW and So Correlation on CD

- Assuming ρ= - 0.5, rodes_3dj_optx_01a_240222 shows the effect of the correlation on the ZDW and SO distributions.
- More negative ρ reduces the probability of large negative dispersion, but it increases the probability of larger positive dispersion in the channel.

No correlation | Negative correlation

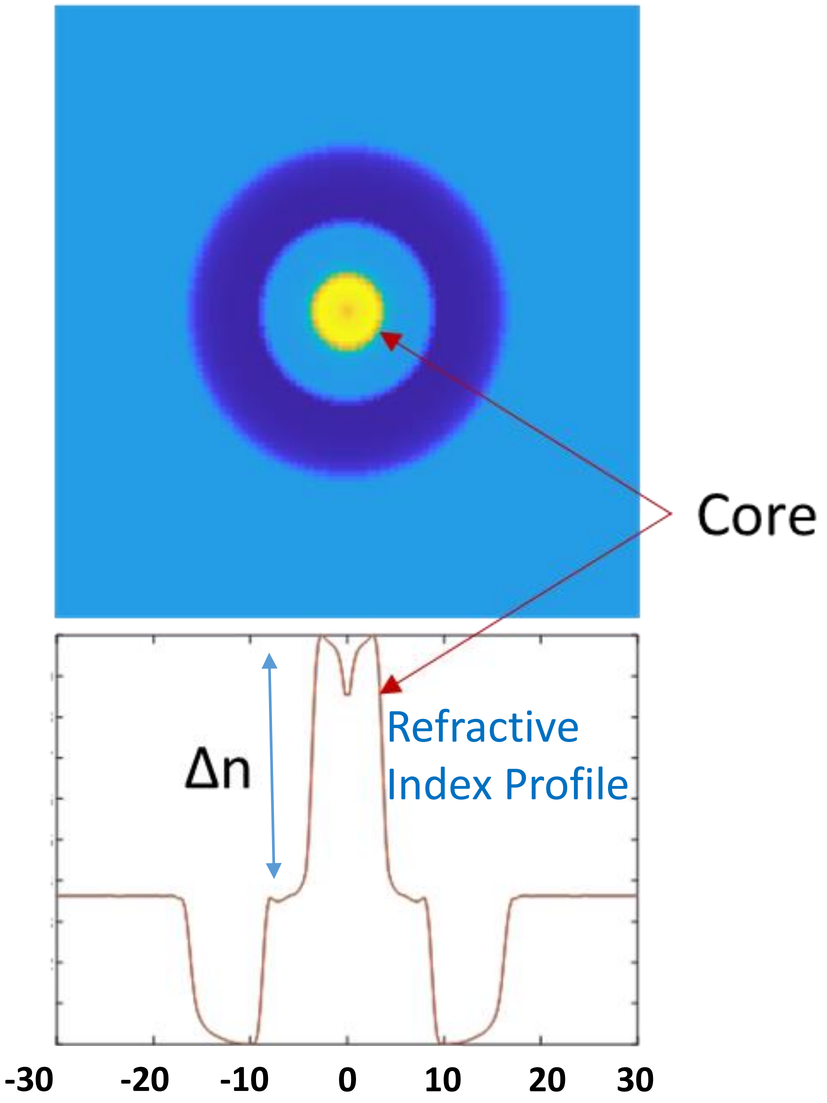


The negative correlation between ZDW and So

Summary of Modeling presented in castro_3dj_optx_01_240222

Fundamental Relationships Among Optical Parameters in Fiber Optics

- Single-mode fiber transmits light through total internal reflection (TIR), necessitating a refractive index contrast, Δn, between the core and cladding.
- The value of Δn and the shape of the refractive index profile determine the relationship between the zero-dispersion wavelength (ZDW) and the slope (So).
- Modeling using real refractive index profiles can help us to understand the degree of dependence between ZDW and So, in ideal conditions and when noise is incorporated.

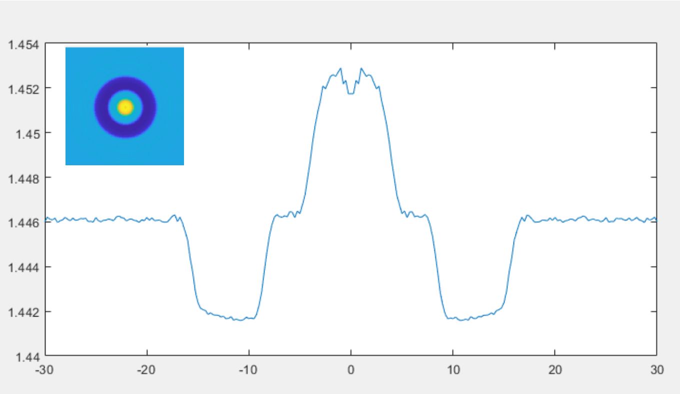


Modeling Method

- The refractive index (RI) profile of 11 fibers form three major vendors was measured.
  - Fibers are G.657 A1 and G.657 A2
  - Fiber were purchased around 2018.
- The refractive index of each fiber was slightly modified, by random noise or distortion of the RI.
  - The distortion was small and from a large set of generated fibers only the ones with cut-off wavelengths around 1260 nm were included in the simulation sets.

Modeling Method

Measured Refractive Index (RI)



Generate Population

2D RI Generator

Dopants parameters

Mode and Dispersion Solver

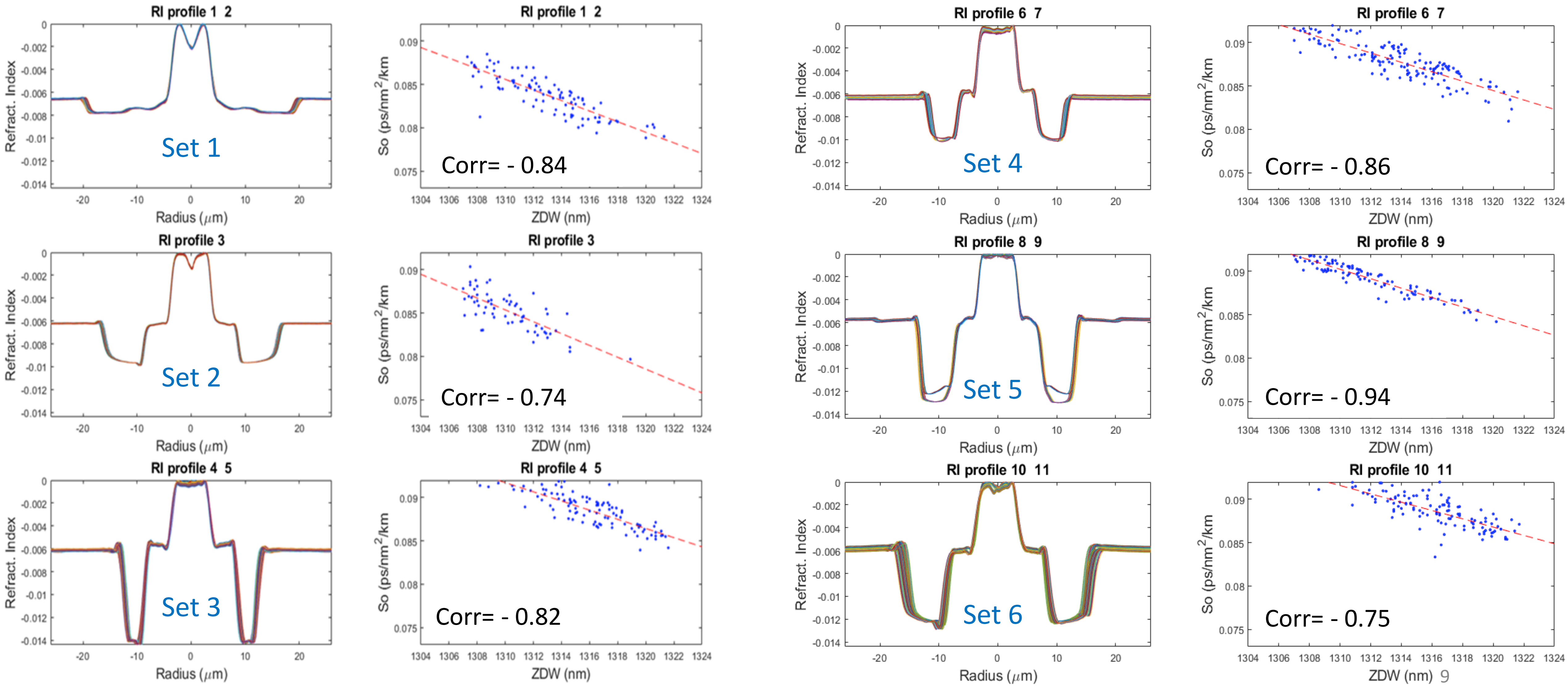
FD- Mode Solver

Output

- Modes
- Group Delays
- Dispersion parameters
  - D
  - ZDW
  - So

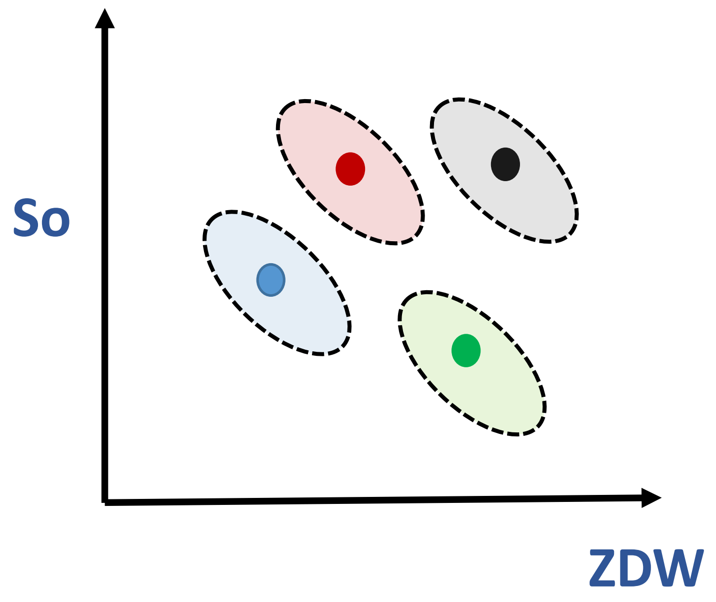
Random noise added to measured refractive index of each fiber to increase population
Cut-off wavelength around 1260 nm is maintained to majority of simulated fibers
More information in castro_3dj_optx_01_240222

Results Grouped by type of Refractive Index profile



Analysis

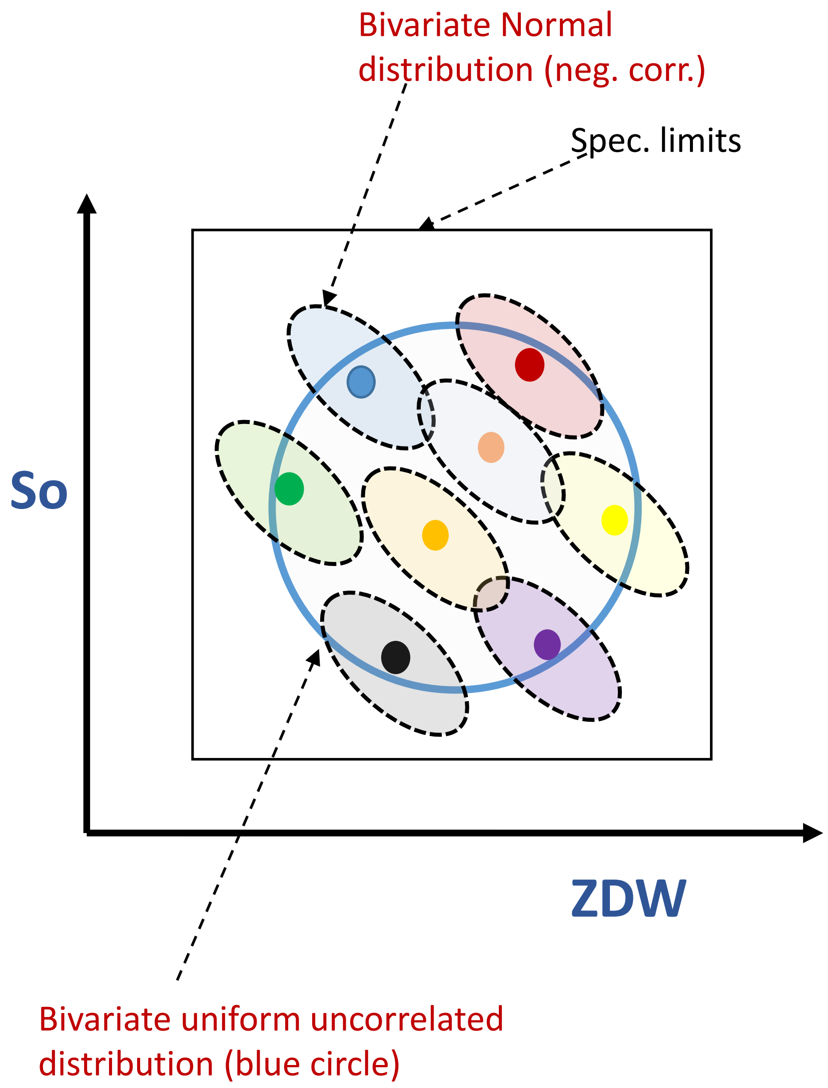
- Modeling results show that for a given fiber design, random perturbations (which can represent a manufacturer's variation), produce a negative correlation between ZDW and So.
- However, when major changes in the fiber design are imposed in the simulation, which could correspond to a different fiber design or process, the ZDW and So show lower correlation.



- Four manufacturers with four different mean parameters.
- The mean parameters are uncorrelated since those depend on the manufacturer.
- The random perturbation within each population show a negative correlation

Proposed Modification on the CD Model

- Instead of assuming a negative correlation for all elements of the distribution, use Cole's approach which utilizes uniform uncorrelated distribution for the mean values ZDW and So.
    - Dots inside the blue circle.
- Those mean values represent design/process parameters chosen by each manufacturer (systematic variations). Those parameters do not follow the negative correlation.
- For each manufacturer, the process randomness produces negative correlations between So and ZDW.
- Here it is proposed initially to use a value around -0.7 based on current simulation results.



Summary and Discussion

- Chromatic dispersion simulations based on measured refractive index profiles show a tendency for negative correlation when random perturbations are imposed on the refractive index.
- Correlation is reduced when mixing processes or fiber designs.
- A negative correlation reduces the probability of sampling worst-case negative dispersion while increasing the probability of worst-case positive dispersion.
- The preliminary work showed here proposes a method to incorporate the negative dispersion in the ZDW and So distributions aiming for a conservative and accurate representation of chromatic dispersion.