

computation of losses in NDRCs :  
a Matlab/FINESSE comparison

# Outline

- Motivations
- Eigenmodes comparison
- Losses comparison
- Summary

# Motivations - 1

- We want to compute the losses in the FP arm cavity due to astigmatism of NDRCs, as they could affect the sensitivity of the interferometer
- To estimate the effect of astigmatism in NDRCs, we defined an overlap integral (OI):

$$\gamma = \frac{\langle E(w1, R1) | E^*(w2, R2) \rangle}{\langle E(w1, R1) || E^*(w1, R1) \rangle}$$

$E_0(w1, R1)$  = FP arm cavity mode

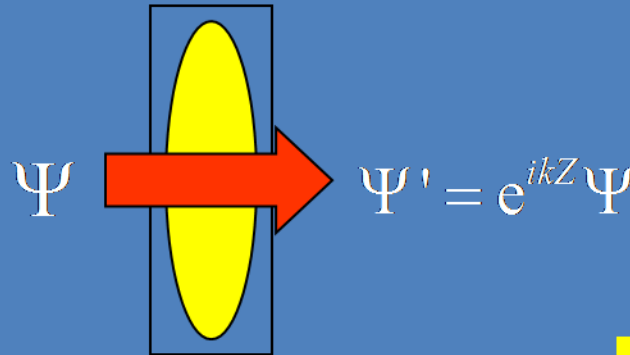
$E_0(w2, R2)$  = PRC astigmatic mode

Fundamental mode:  $E_0 = e^{-jP(z)} \exp\left\{-x^2\left(\frac{1}{w_x^2} + j\frac{k}{2R_x}\right) - y^2\left(\frac{1}{w_y^2} + j\frac{k}{2R_y}\right)\right\}$

# Motivations - 2

- The OI allows to compute the mis-matching between the astigmatic mode of the ND-PRC, the mode of the FP in the arm, the input beam
- TCS defined independently the same OI to account for thermal effects :

$$\gamma = \langle \Psi, e^{ikZ} \Psi \rangle$$



**Fafone, Rocchi –  
AdV biweekly meeting  
12.03.09**

$$\gamma = 2\pi \int_0^a e^{ikZ(r)} |\Psi(r)|^2 r dr$$

**Losses :**  $L = 1 - |\gamma|^2$

From J.Y. Vinet,  
Thermal Simulations Meeting,  
Cascina 1.10.08

# Motivations - 3

- We developed a Matlab code to compute the ND-PRC astigmatic mode and its overlap integrals with input beam and FP mode.

- Which is the relation of the OI with power losses ?

$$P = P_0 \cdot G_{\text{PRC}} \cdot G_{\text{FP}} \cdot \gamma_{\text{input}}^2 \cdot \gamma_{\text{FP}}^2$$

- Finesse can compute the power stored in the FP arm and PRC cavities
- A comparison between Finesse and Matlab simulations is needed

# Eigenmodes comparison – scen. 2

- Null tilt of PRC mirrors (PRM3, PRM2) :

	Finesse :	z	zR	Matlab :	z	%	zR	%
PRM1	"cav" PRC on M1	1,65509	0,506355		1,65619	-0,0665	0,504715	0,324
PRM2		8,8449173	0,506355		8,84381	0,0125	0,504715	0,324
PRM3		6,31298	0,004264		6,31297	0,0002	0,004251	0,305
AR		1009,22	112,78		1009,28	-0,0059	112,51	0,239
HR (sub)		1400,01	149,6		1400,09	-0,0057	149,26	0,227

- 1,3 deg tilt + ITM AR RoC = 1e+25 :

	Finesse :	z	zR	Matlab :	z	%	zR	%
PRM1 t	"cav" PRC on M1	1,62305	0,550844		1,6242773	-0,07562	0,549240527	0,291
PRM2 t		8,87695	0,550844		8,875722693	0,01383	0,549240527	0,291
PRM3 t		6,3131	0,00460396		6,31308585	0,00022	0,004591789	0,264
AR t		964,082	111,324		964,1344738	-0,00544	111,1011414	0,200
HR (sub) t		1397,36	161,378		1397,438257	-0,00560	161,0555477	0,200
PRM1 s		1,29805	0,815189		1,299444482	-0,10743	0,814517373	0,082
PRM2 s		9,20195	0,815189		9,200555518	0,01515	0,814517372	0,082
PRM3 s		6,31637	0,00636659		6,316360425	0,00015	0,006363148	0,054
AR s		952,694	151,968		952,6920431	0,00021	151,9752723	-0,005
HR (sub) s		1380,85	220,297		1380,850966	-0,00007	220,307914	-0,005

- z = distance to waist ; zR = Rayleigh range ; t = tang. ; s = sagitt.
- % = percentage difference between Matlab and Finesse values

## Eigenmodes comparison – scen. 2

- The percentage difference between Matlab/ Finesse varies for the Rayleigh range  $z_R$  of the eigenmode, as the PRC mirror tilt or the IM AR curvature have different values.
- The percentage difference for the distance to waist  $z$  doesn't show any significant variation with respect to the same parameters.
- This point should be further investigated.

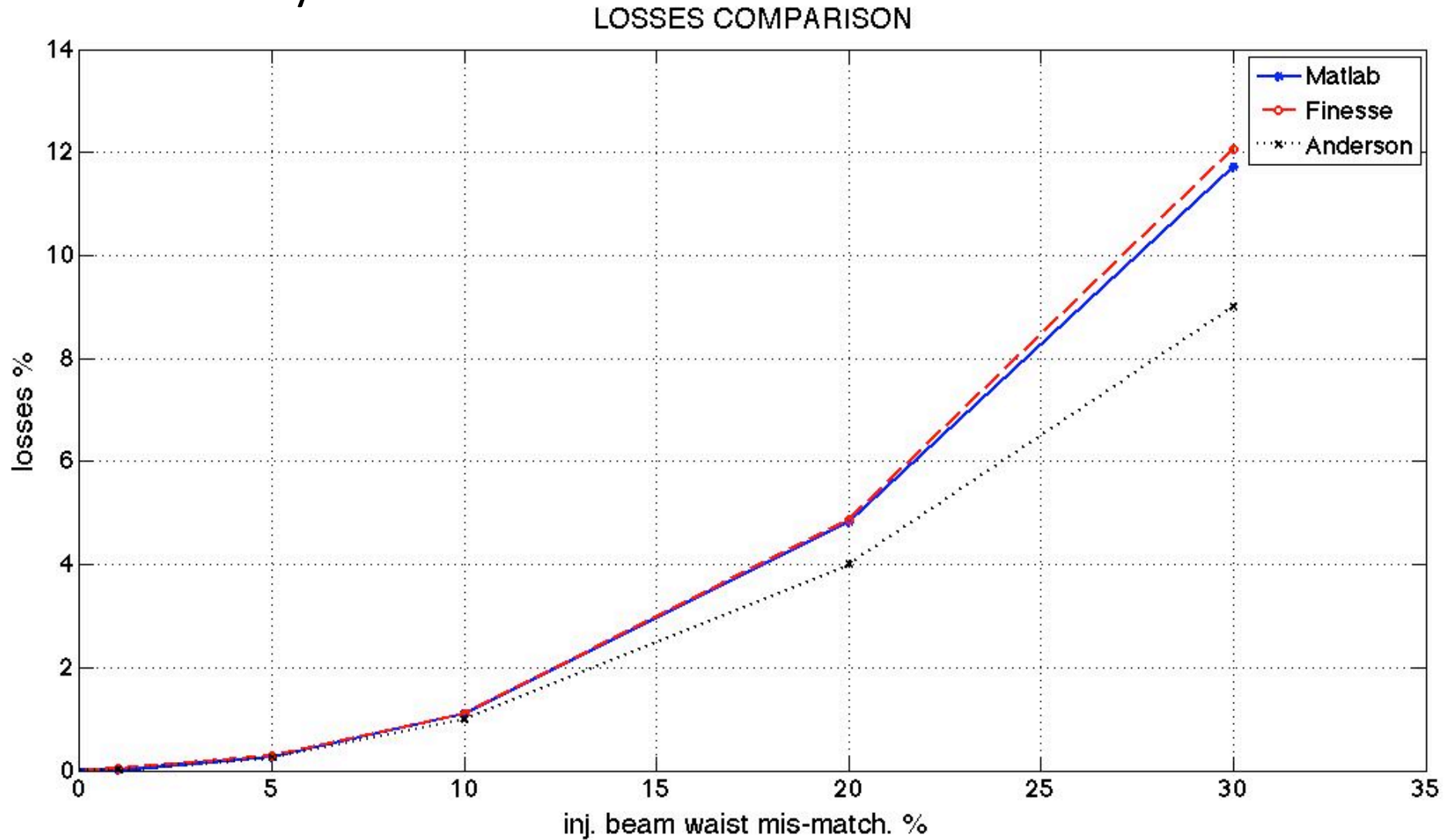
# Power Losses Comparison -1

- A simple FP cavity has been simulated, like the one of AdV arm, with Matlab and Finesse
- A mis-matching (with respect to the eigenmode of the cavity) beam is then injected in the cavity



# Power Losses - 1

- FP arm cavity :



Anderson D. , Appl. Opt. Vol. 23 , No. 17 , 1984

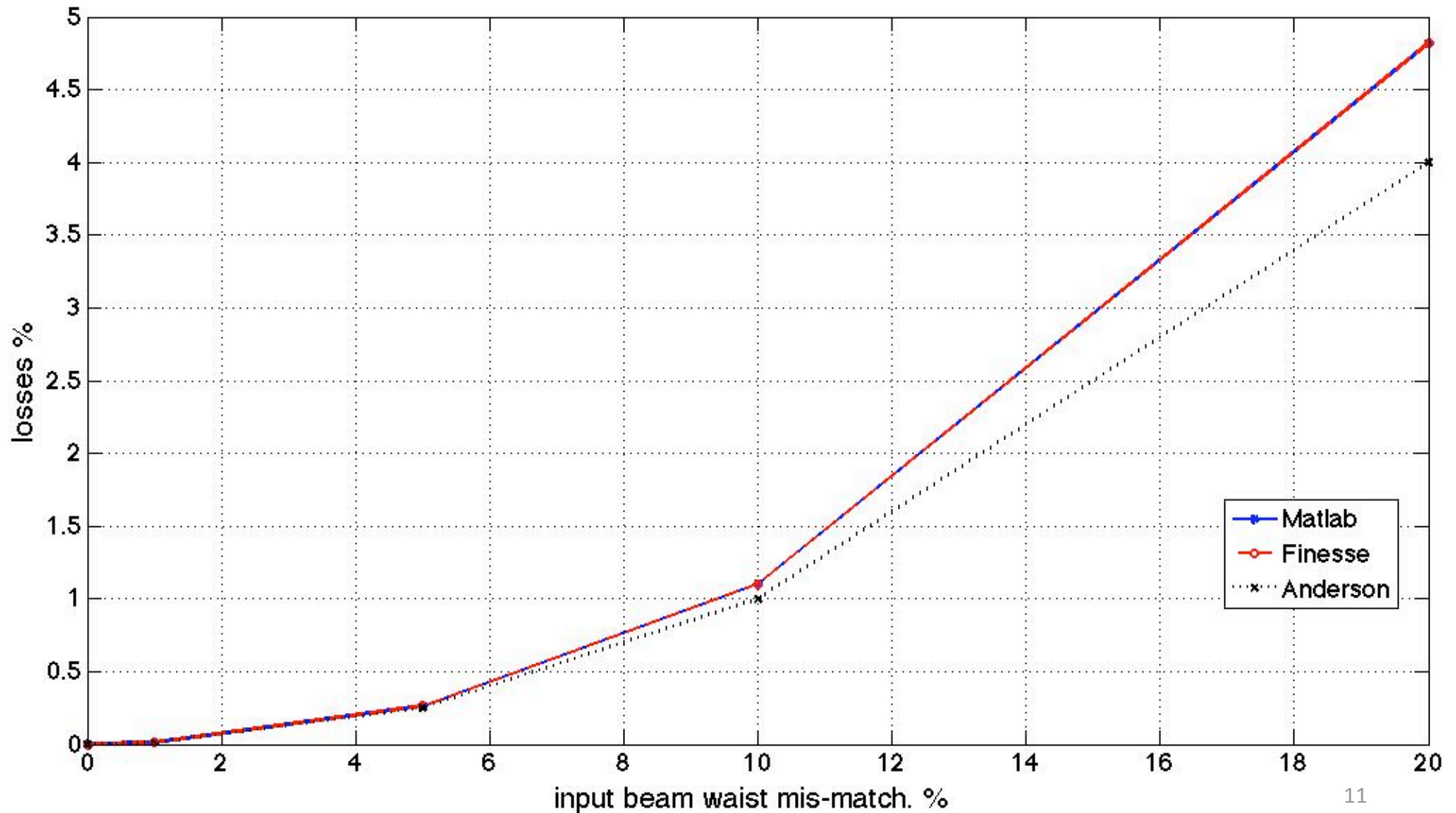
# Power Losses Comparison -2

- A system of two coupled cavities has been simulated, like the one composed by AdV FP arm cav. + PRC, with Matlab and Finesse
- Then, two simple cases can be given among others :
  - A mis-matching (with respect to the eigenmode of the cavity) beam is injected in the cavity
  - or
  - A mis-match between the two cavities is introduced, varying PRM1 RoC

# Power Losses - 2

- FP / PRC coupled cavities, **NULL TILT** of PRC mirrors, mis-match. input beam :

LOSSES COMPARISON



# Power Losses Comparison - 3

- A system of two coupled cavities has been simulated, like the one composed by AdV FP arm cav. + PRC, with Matlab and Finesse
  - A mis-match between the two cavities is introduced, varying PRM1 RoC : losses are higher in Finesse than in Matlab.

# Summary

- For matched coupled cavities, the power losses from Finesse and the coupling factor  $\gamma^2$  from the Matlab code give same results.
- Point still under investigation :
  - **mis-match between the two cavities**, losses are higher in Finesse than in Matlab.
- A comparison for the astigmatic PRC case must be realised.