5
Double-interface lossless modes in ϵ_r'-μ_r' parameter space

Tables

Item	Topic	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7
1	Interfaces	1	1	2	1	2
2	Types	ENG,DNG	DPS,ENG,DNG,MNG	DPS,ENG,DNG,MNG	ENG	ENG
3	ϵ_r,μ_r	complex	real	real	complex	complex
4	Dispersion	yes	no	no	no	no
5	Free β	yes	yes	yes	yes	yes
6	Loaded β	yes	no	no	yes	yes
7	Configuration	O,K	free	free	O,K	G
8	$\mathcal{R}$	yes	no	no	yes	yes
9	G–H	yes	no	no	no	no
10	E and H	no	yes	yes	yes	yes
11	s_z	no	yes	yes	yes	yes
12	s_x	no	no	no	yes	yes
13	η	yes	no	no	yes	yes
14	v_{ph} and v_{group}	yes	no	no	no	no
15	Charge density	no	no	no	yes	yes

Table 2.10. List of topics investigated in chapters 3-7.

Item	Topic	Chapter 5
1	Interfaces	2
2	Types	DPS,ENG,DNG,MNG
3	ϵ_r, μ_r	real
4	Dispersion	no
5	Free β	yes
6	Loaded β	no
7	Configuration	free
8	$\mathcal{R}$	no
9	G–H	no
10	E and H	yes
11	s_z	yes
12	s_x	no
13	η	no
14	v_{ph} and v_{group}	no
15	Charge density	no

Table 5.1. List of topics investigated in this chapter.

Medium		ϵ_i	μ_i	n_i
Cover	c	2.25	1	1.5
Guide	g	3.0625	2.	2.47487
Substrate	s	2.25	1	1.5

Table 5.2. The parameters ϵ_i, μ_i and n_i of the substrate, guide and cover. These parameters are used to generate all the media types discussed in this chapter.

Medium	Type	r_i	ϕ_i(deg)
Cover	DPS	2.46221	23.9625
Guide	DPS	3.65772	33.147
Guide	ENG	3.65772	146.853
Guide	DNG	3.65772	213.147
Guide	MNG	3.65772	326.853
Substrate	DPS	2.46221	23.9625

Table 5.3. The sets (r_s,ϕ_s), (r_g,ϕ_g) and (r_c,ϕ_c) used to generate all the guide media types discussed in this chapter.

	Thin	d_{cr}	Thick
d_g(nm)	25	51.1624	500

Table 5.4. The critical thickness of ENG-, DNG- and MNG-type guides, d_{cr}, below which they can support specially confined modes, together with the choice of thin and thick guides used for the examples presented at the end of this chapter.

Case	Type	Mode	Symmetry	d_g (nm)
1	DPS	TE	Even	500
2	DPS	TE	Odd	500
3	DPS	TM	Even	500
4	DPS	TM	Odd	500
5	DNG	TE	Even	500
6	DNG	TE	Odd	500
7	DNG	TM	Even	500
8	DNG	TM	Odd	500
9	ENG	TM	Even	25
10	ENG	TM	Odd	25
11	MNG	TE	Even	25
12	MNG	TE	Odd	25
13	DPS	TE	Even	25
14	DPS	TM	Even	25
15	DNG	TE	Odd	25
16	DNG	TM	Odd	25

Table 5.5. 16 examples, arranged according to the guide type and thickness, the mode it supports and its symmetry.

Figures

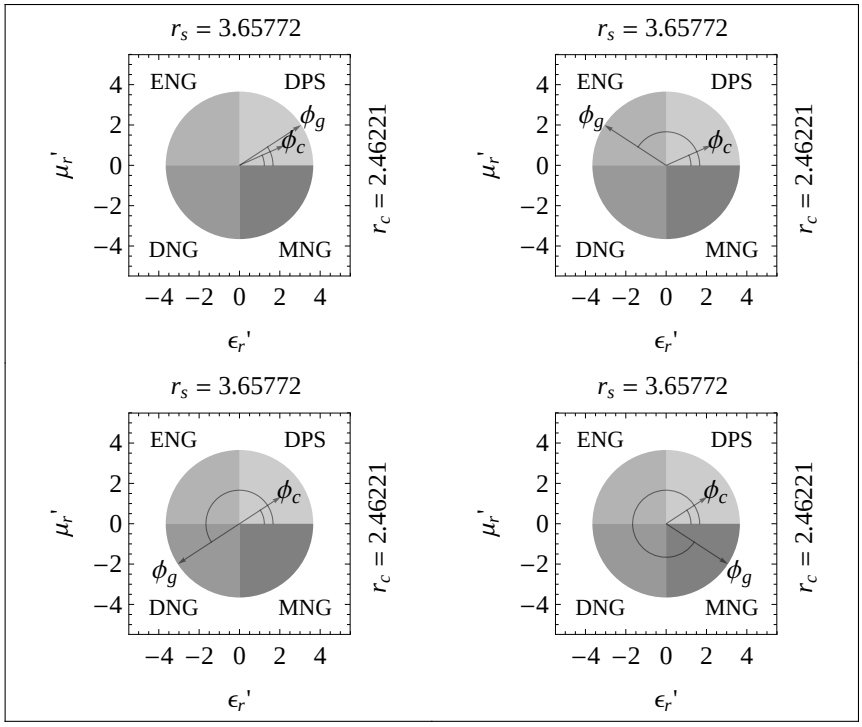

Fig. 5.3. The four guide media-types consisting of (top left) DPS/DPS/DPS-type, (top right) DPS/ENG/DPS-type, (bottom left) DPS/MNG/DPS-type and (bottom right) DPS/MNG/DPS-type structures, where the substrate and cover are identical media.

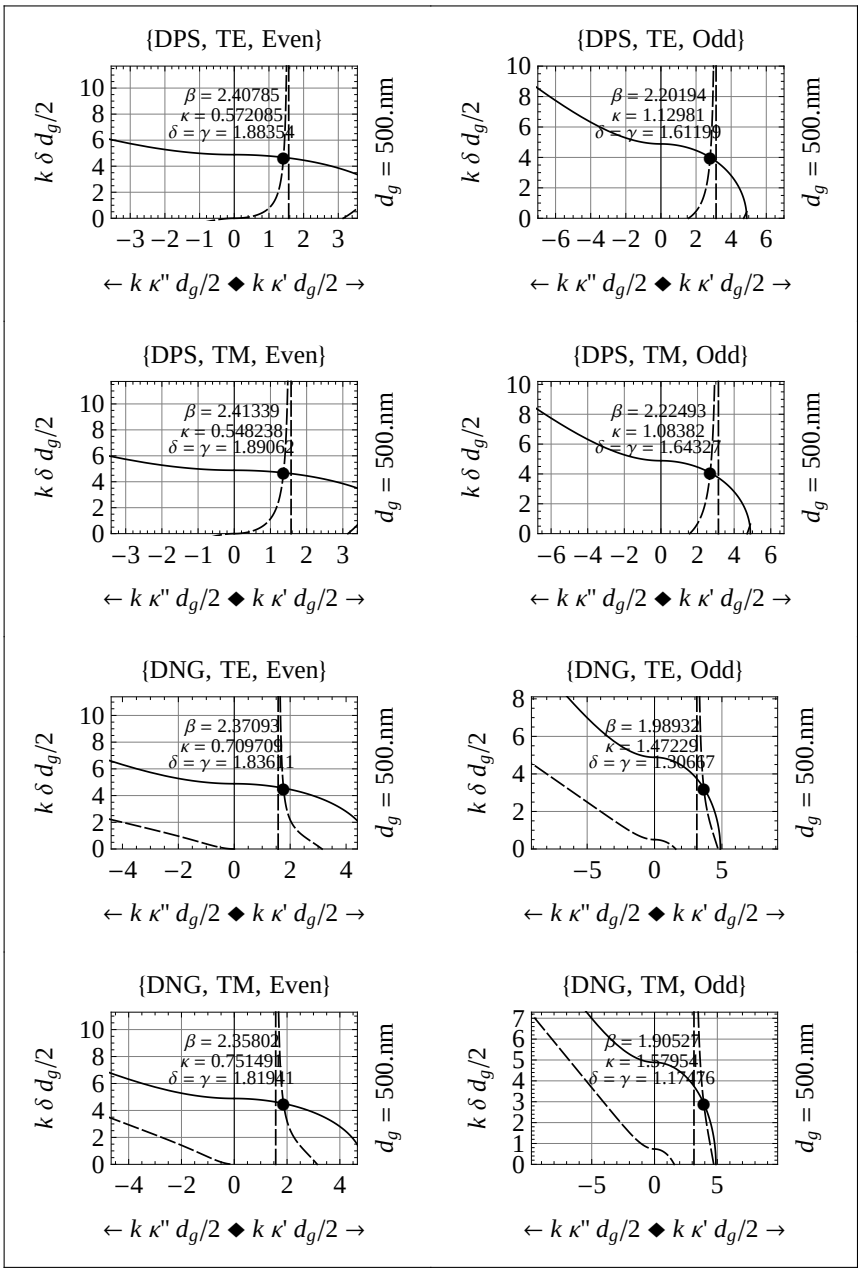

Fig. 5.4. Solutions of the mode equations for guides with d_g = 500 nm showing the intersection of the right- and left-hand sides of Eqs. (2.163) and (2.167).

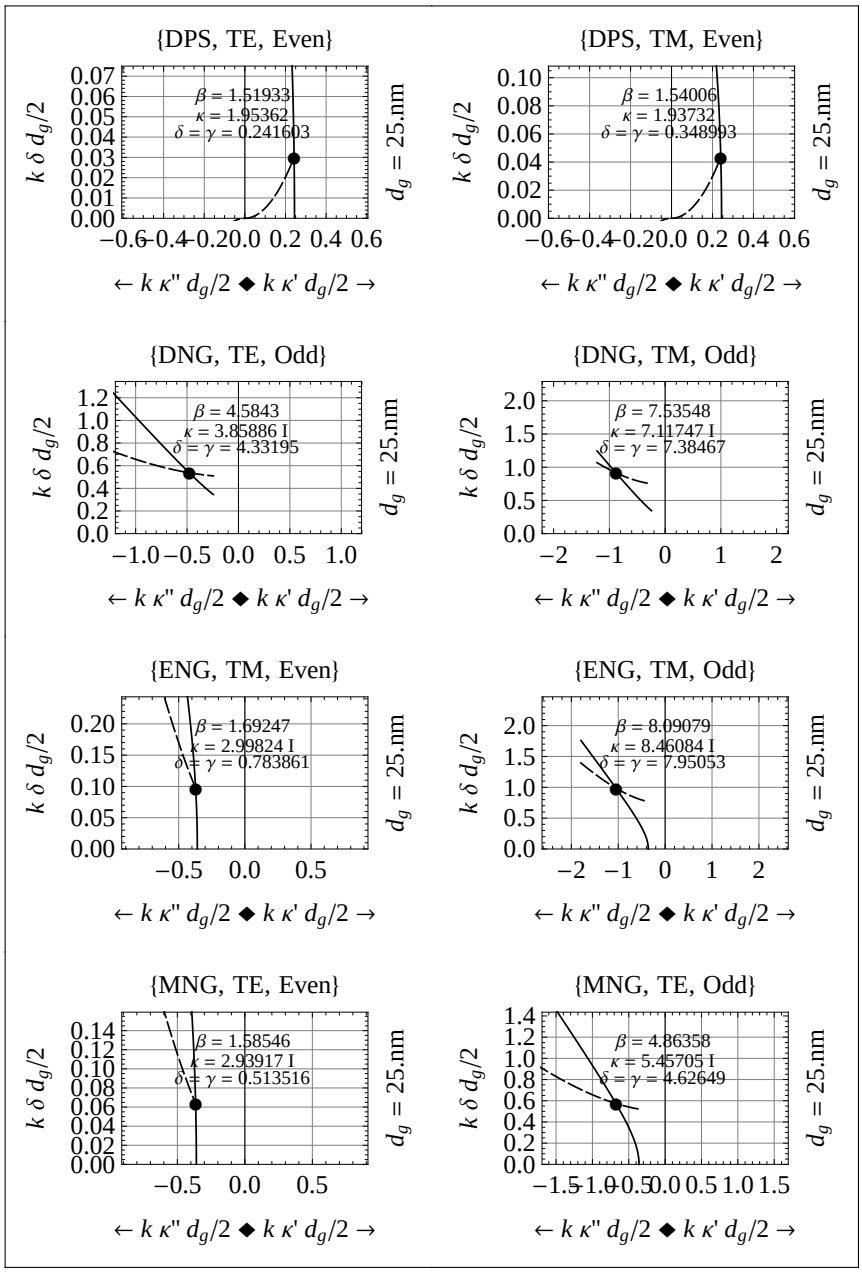

Fig. 5.5. Selected solutions of the mode equations for guides with d_g = 25 nm showing the intersection of the right- and left-hand sides of Eqs. (2.163) and (2.167).

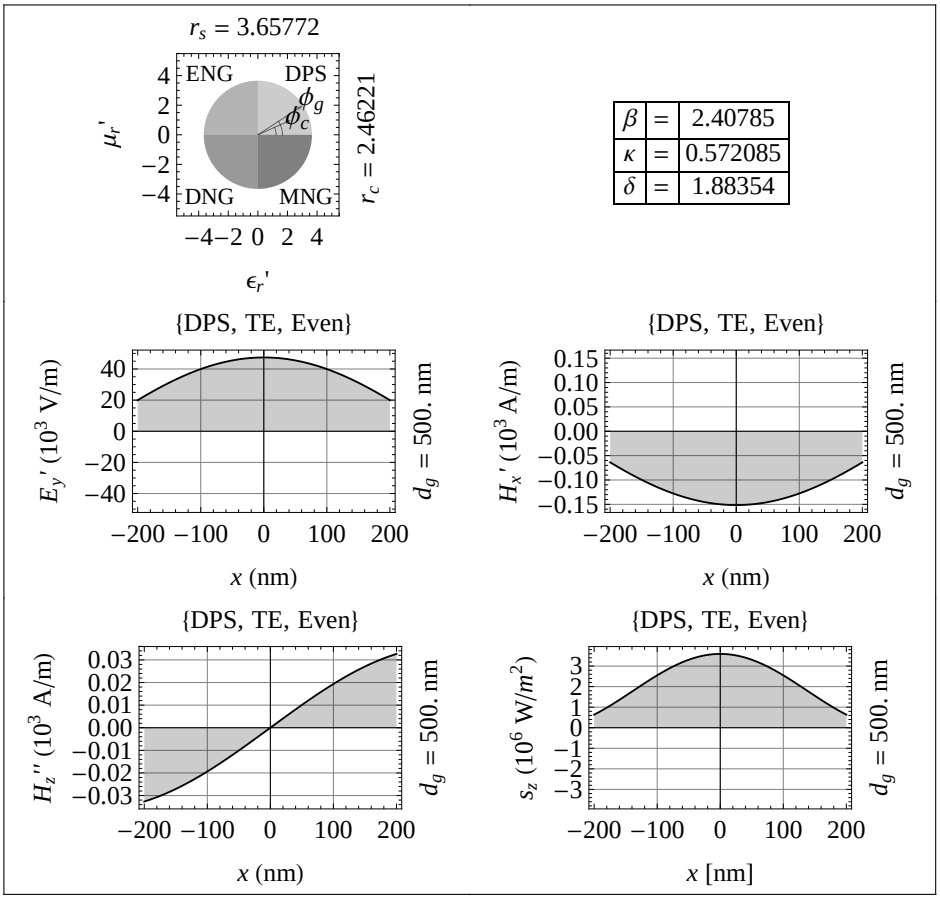

Fig. 5.7. The complete solution of an even TE mode supported by a DPS/DPS/DPS-type structure with d_g= 500 nm.

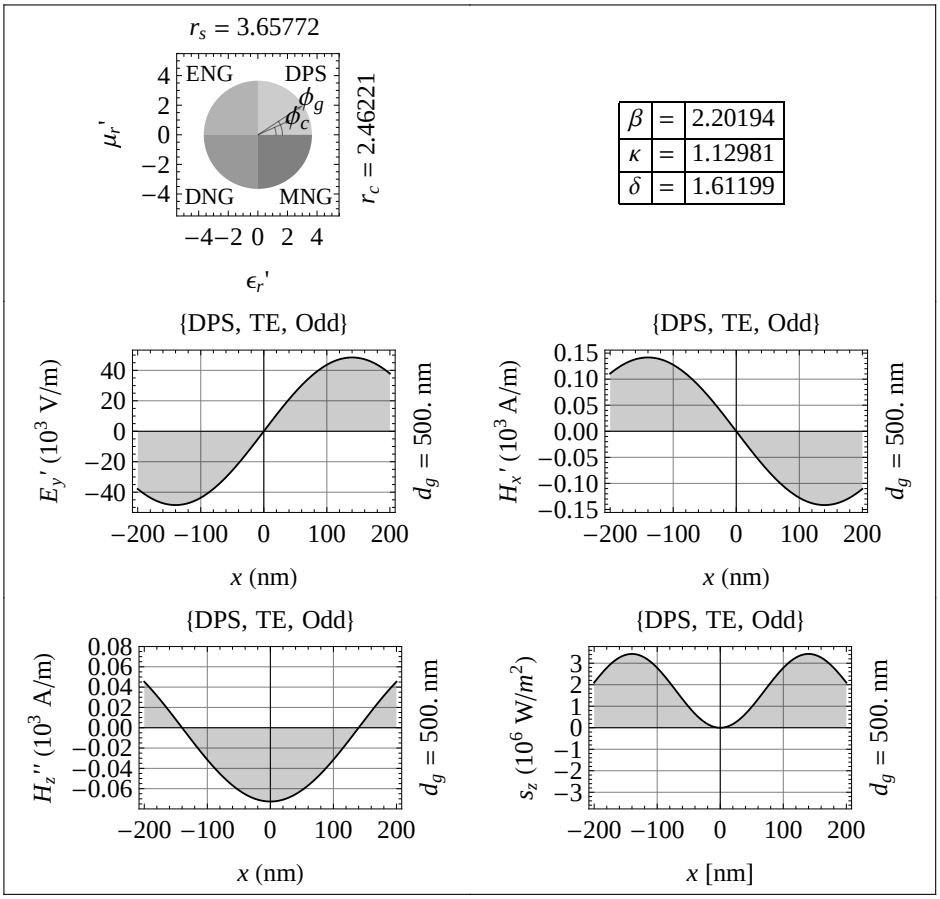

Fig. 5.8. The complete solution of an odd TE mode supported by a DPS/DPS/DPS-type structure with d_g= 500 nm.

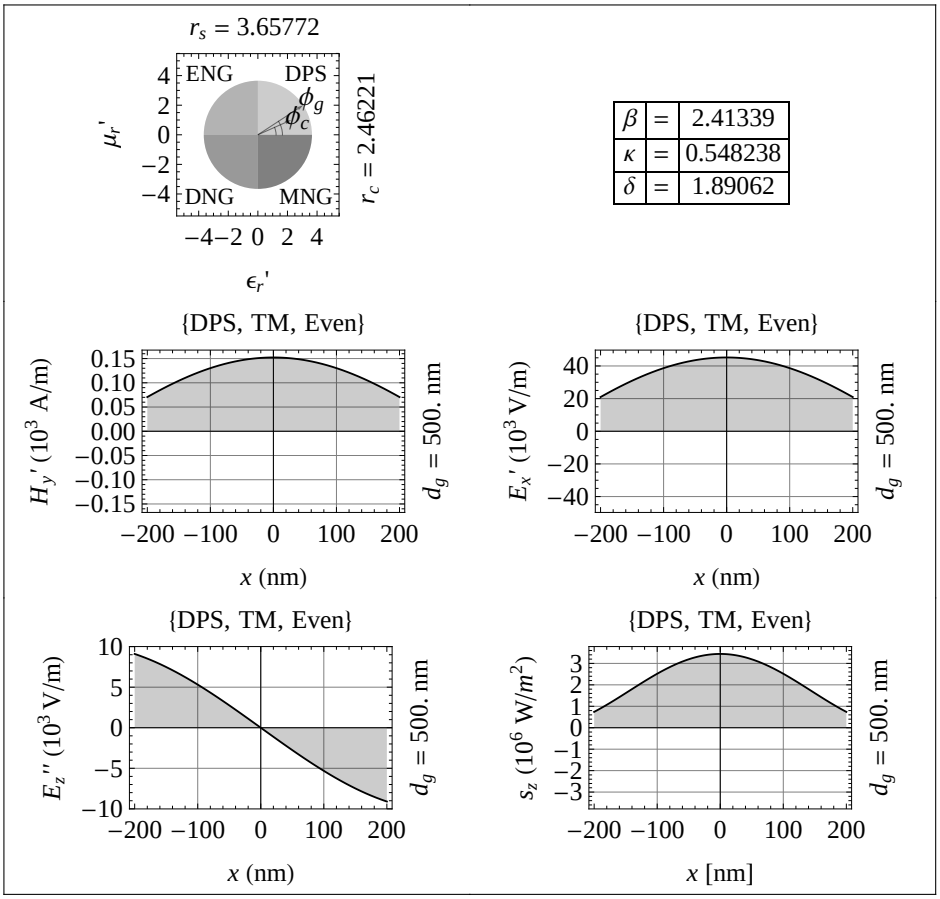

Fig. 5.9. The complete solution of an even TM mode supported by a DPS/DPS/DPS-type structure with d_g= 500 nm.

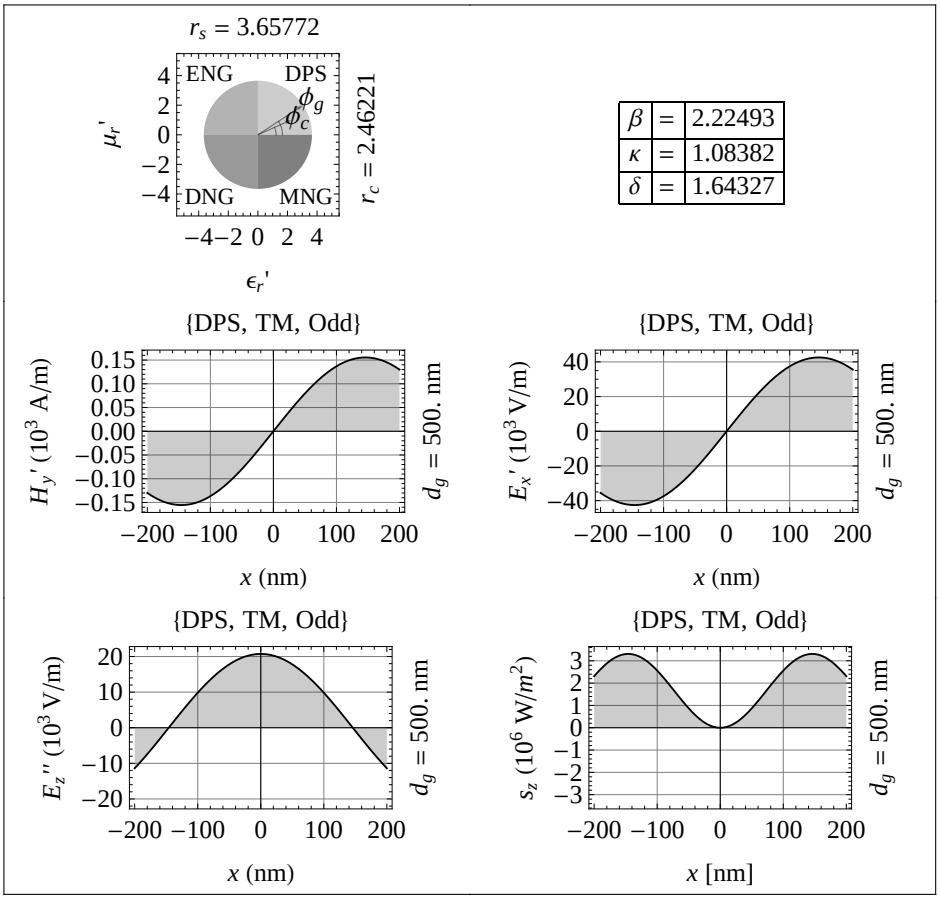

Fig. 5.10. The complete solution of an odd TE mode supported by a DPS/DPS/DPS-type structure with d_g= 500 nm.

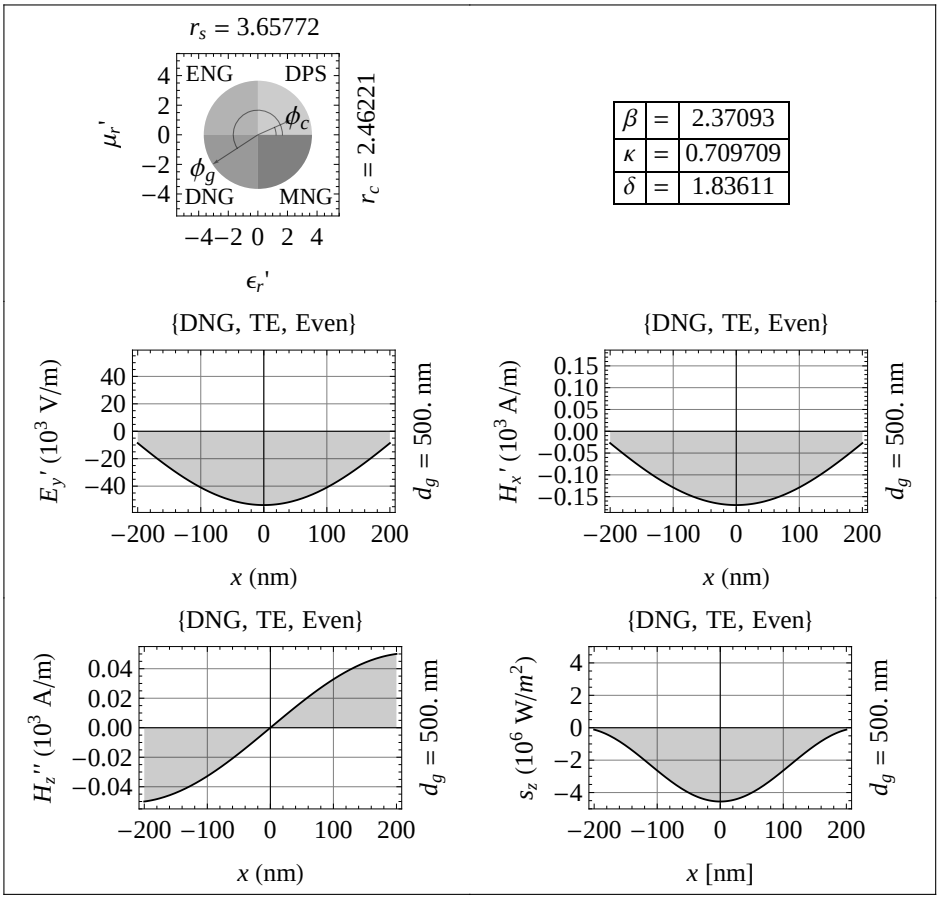

Fig. 5.11. The complete solution of an even TE mode supported by a DPS/DNG/DPS-type structure with d_g= 500 nm.

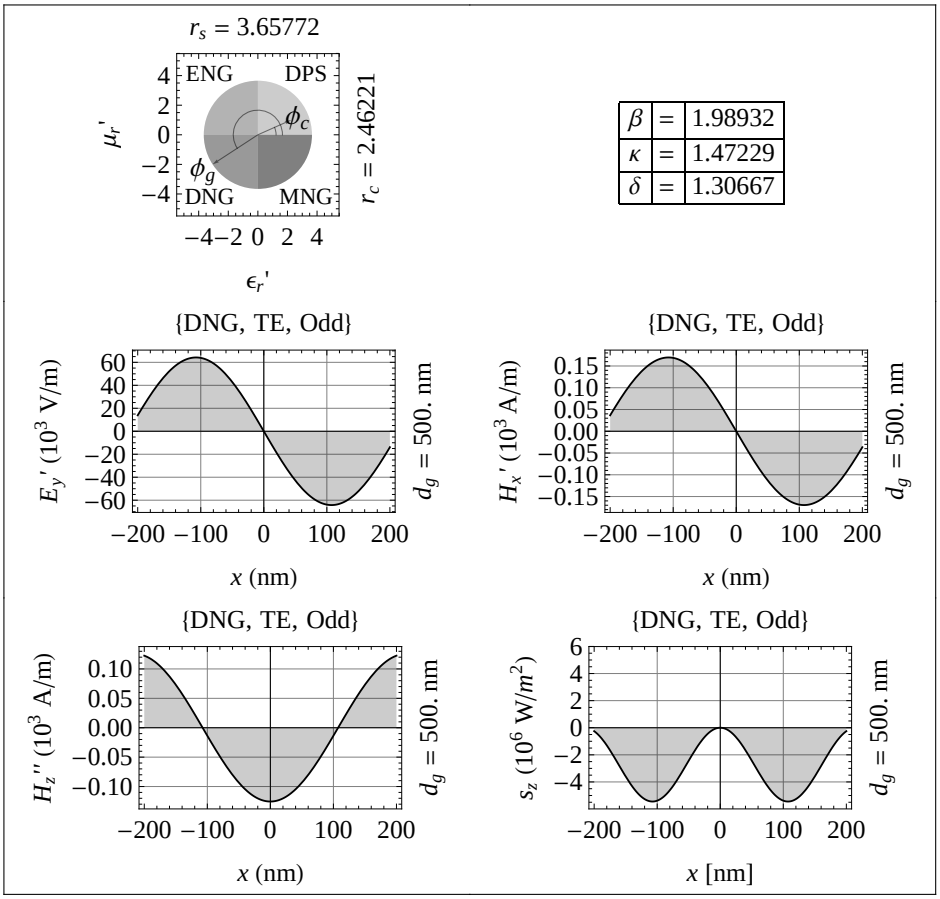

Fig. 5.12. The complete solution of an odd TE mode supported by a DPS/DNG/DPS-type structure with d_g= 500 nm.

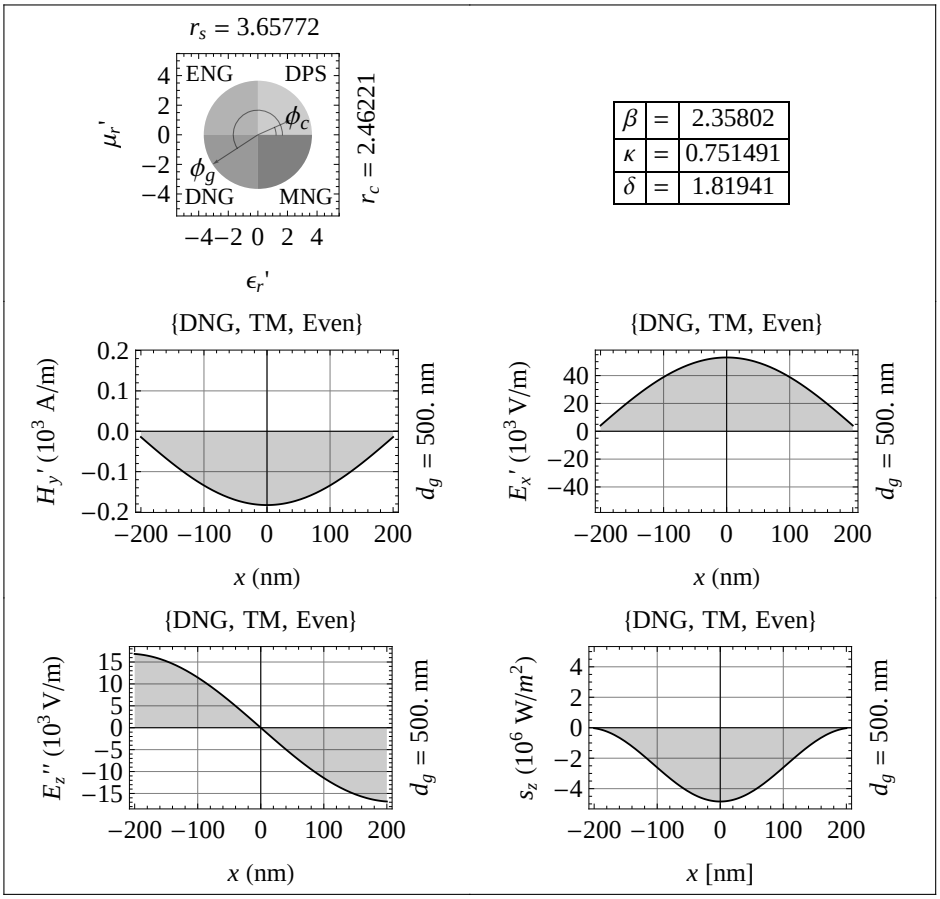

Fig. 5.13. The complete solution of an even TM mode supported by a DPS/DNG/DPS-type structure with d_g= 500 nm.

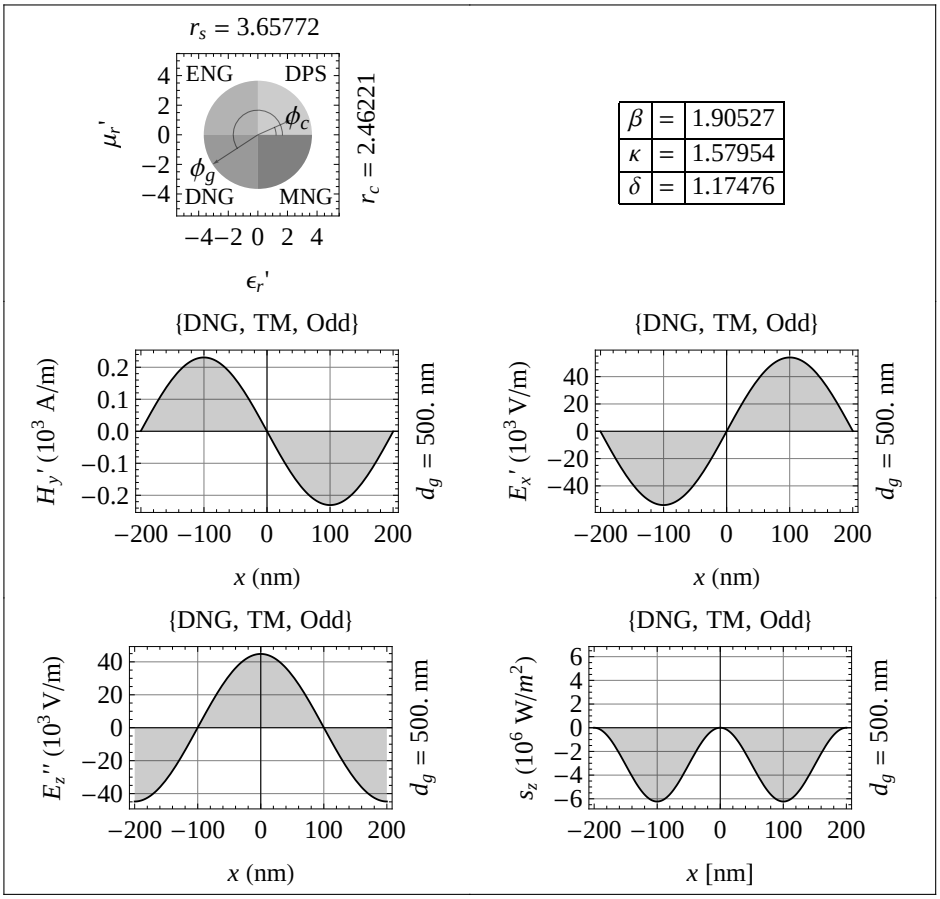

Fig. 5.14. The complete solution of an odd TM mode supported by a DPS/DNG/DPS-type structure with d_g= 500 nm.

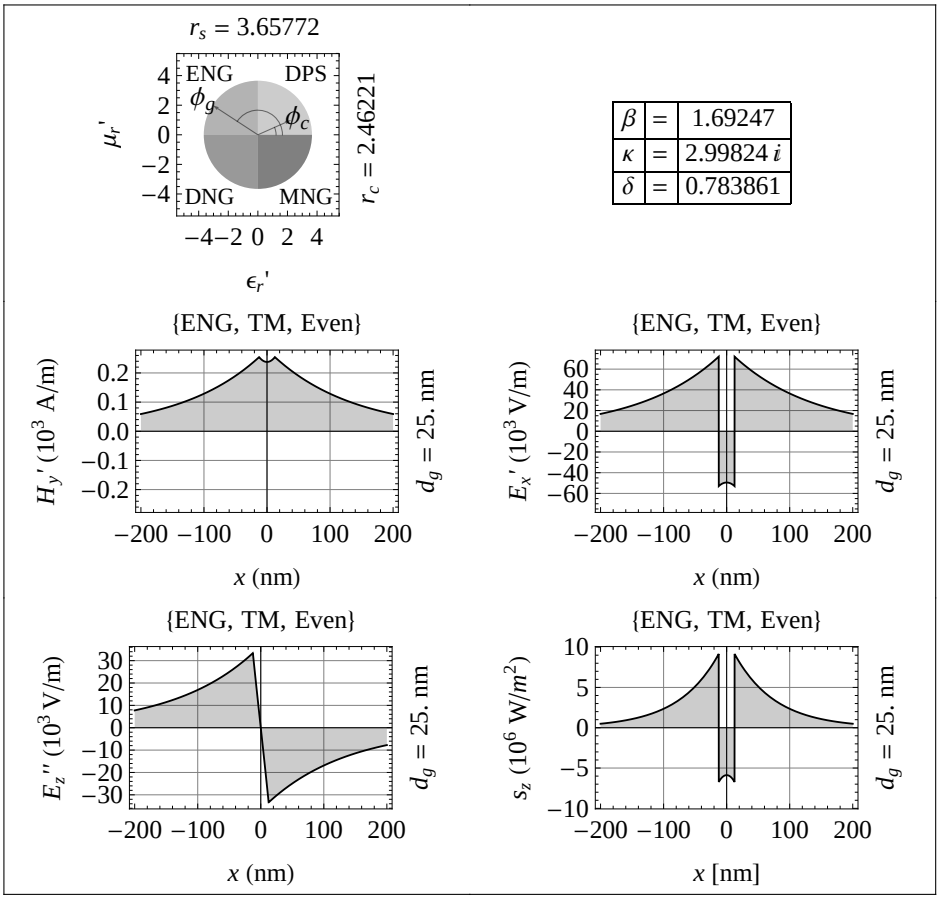

Fig. 5.15. The complete solution of an even TM mode supported by a DPS/ENG/DPS-type structure with d_g= 25 nm.

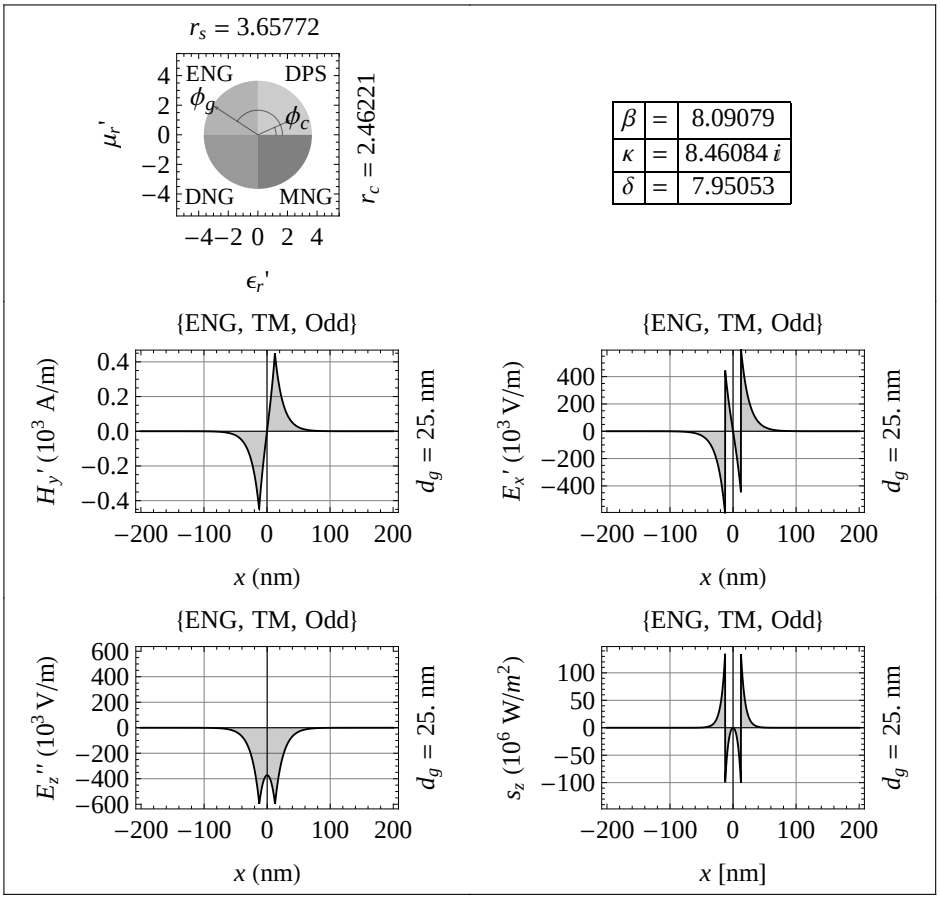

Fig. 5.16. The complete solution of an odd TM mode supported by a DPS/ENG/DPS-type structure with d_g= 25 nm.

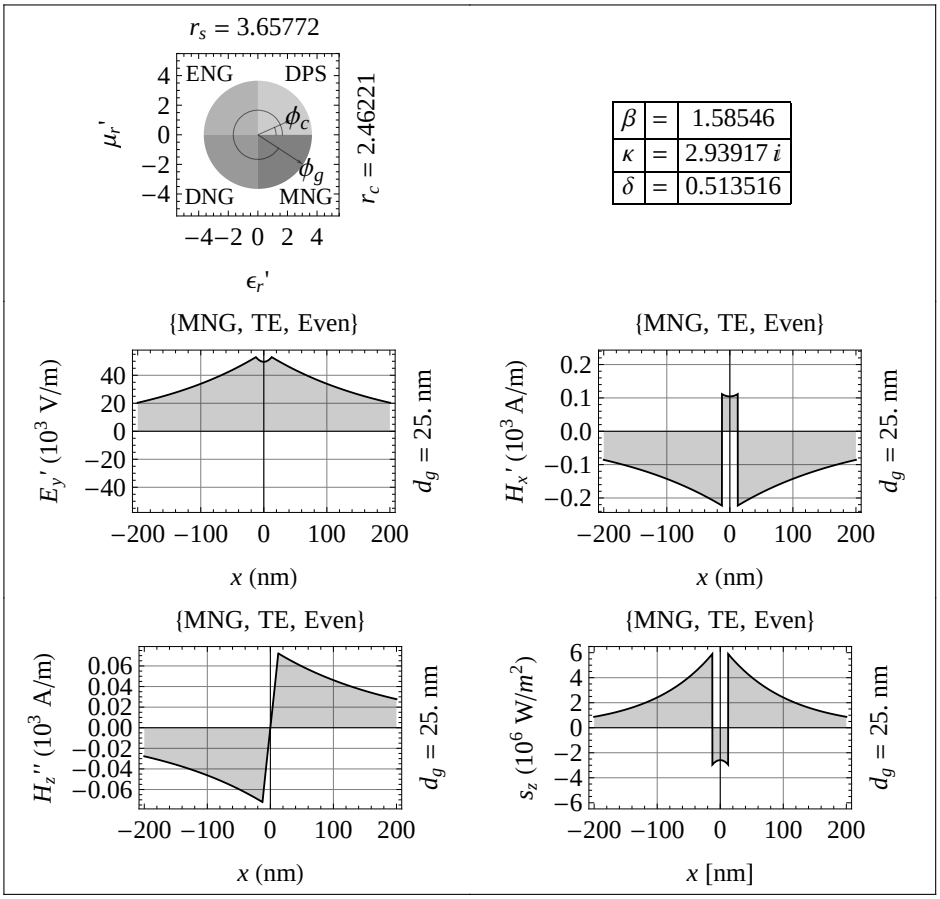

Fig. 5.17. The complete solution of an even TE mode supported by a DPS/MNG/DPS-type structure with d_g= 25 nm.

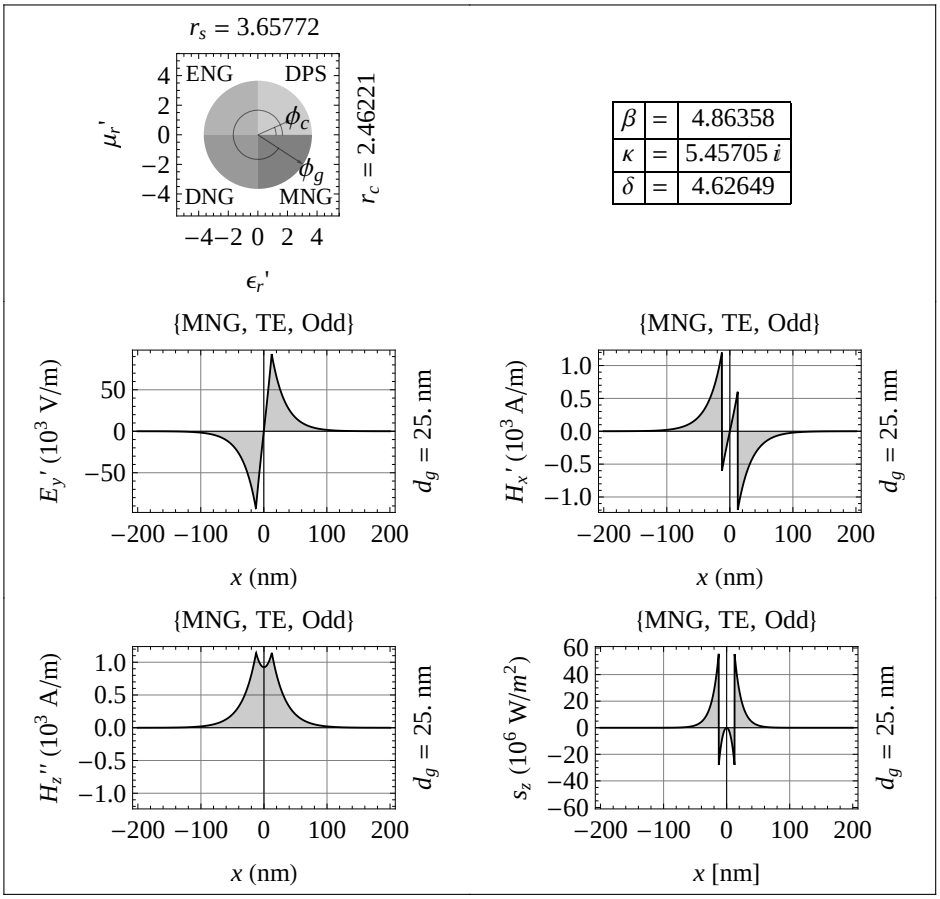

Fig. 5.18. The complete solution of an odd TE mode supported by a DPS/MNG/DPS-type structure with d_g= 25 nm.

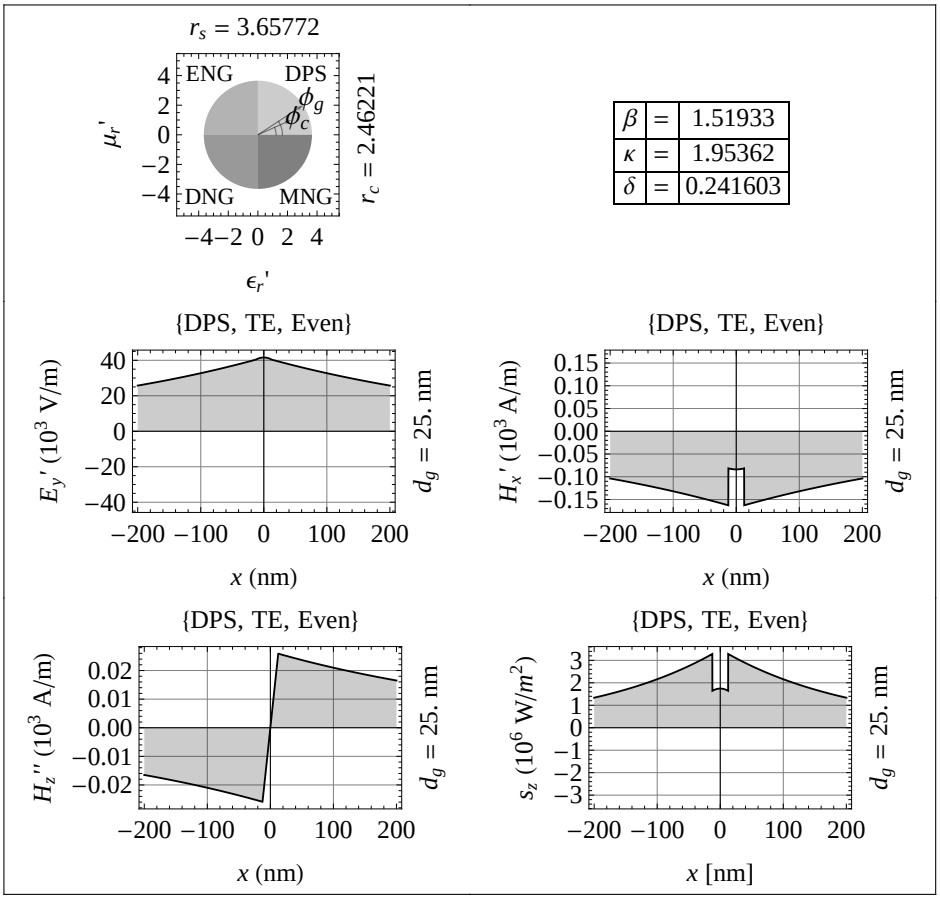

Fig. 5.19. The complete solution of an even TE mode supported by a DPS/DPS/DPS-type structure with d_g= 25 nm.

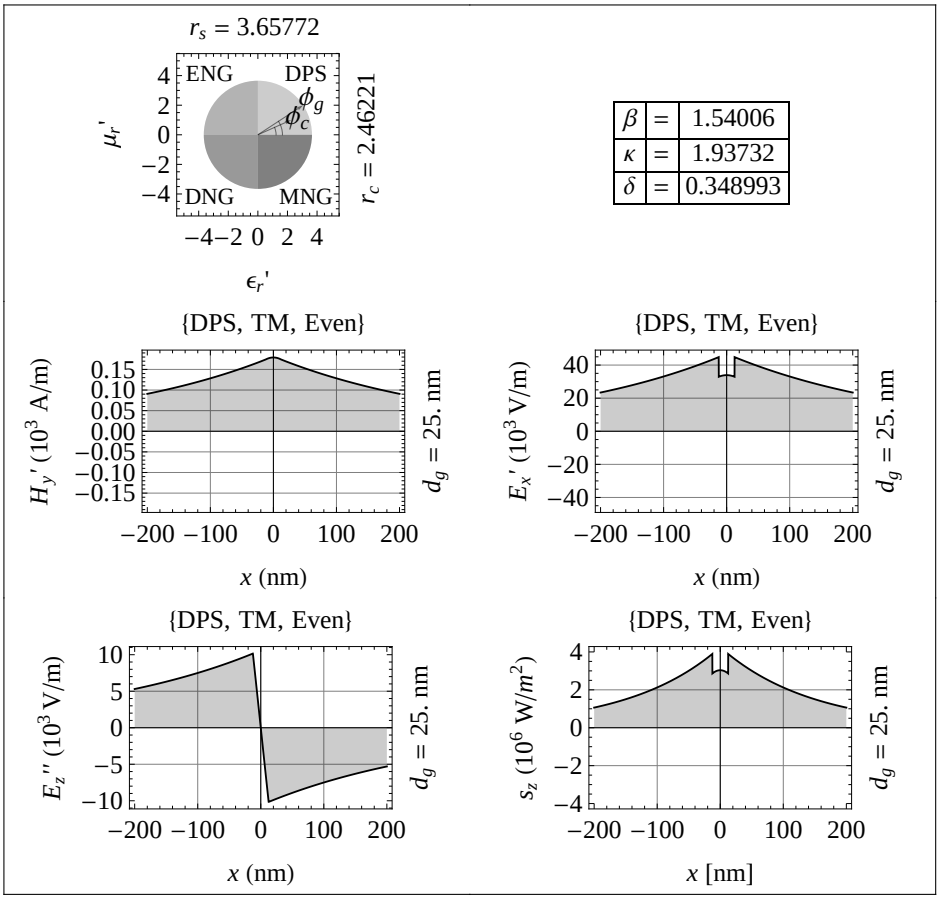

Fig. 5.20. The complete solution of an even TM mode supported by a DPS/DPS/DPS-type structure with d_g= 25 nm.

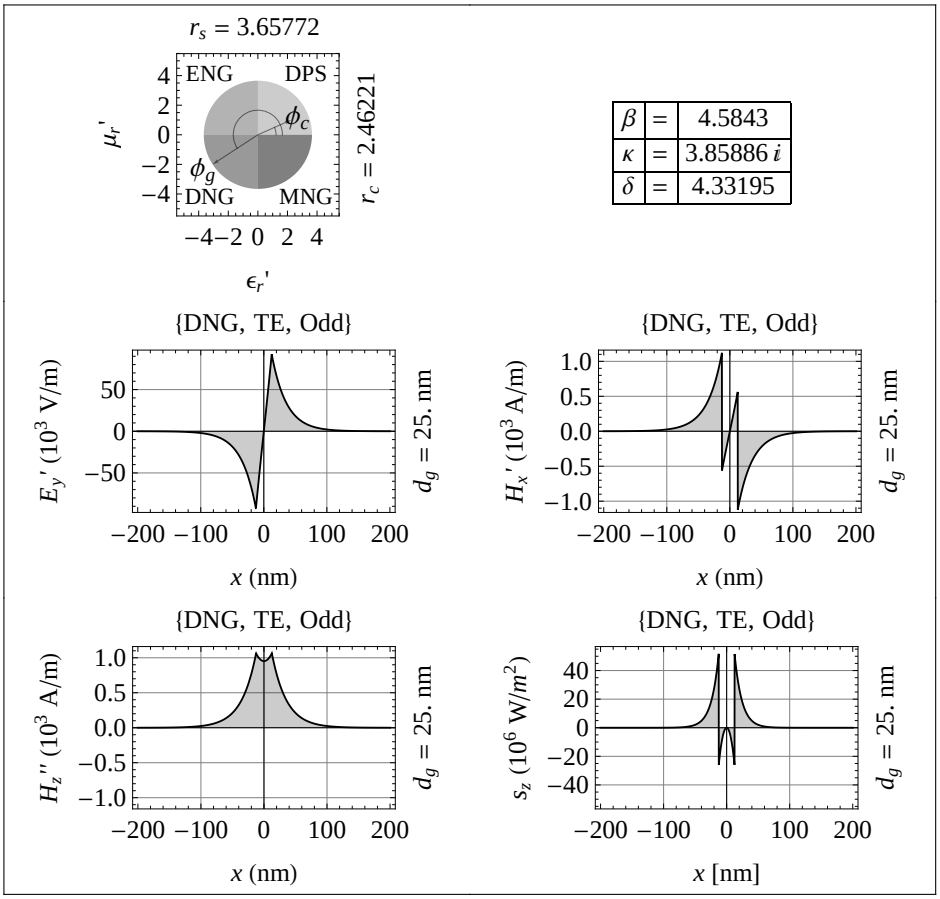

Fig. 5.21. The complete solution of an odd TE mode supported by a DPS/DNG/DPS-type structure with d_g= 25 nm.

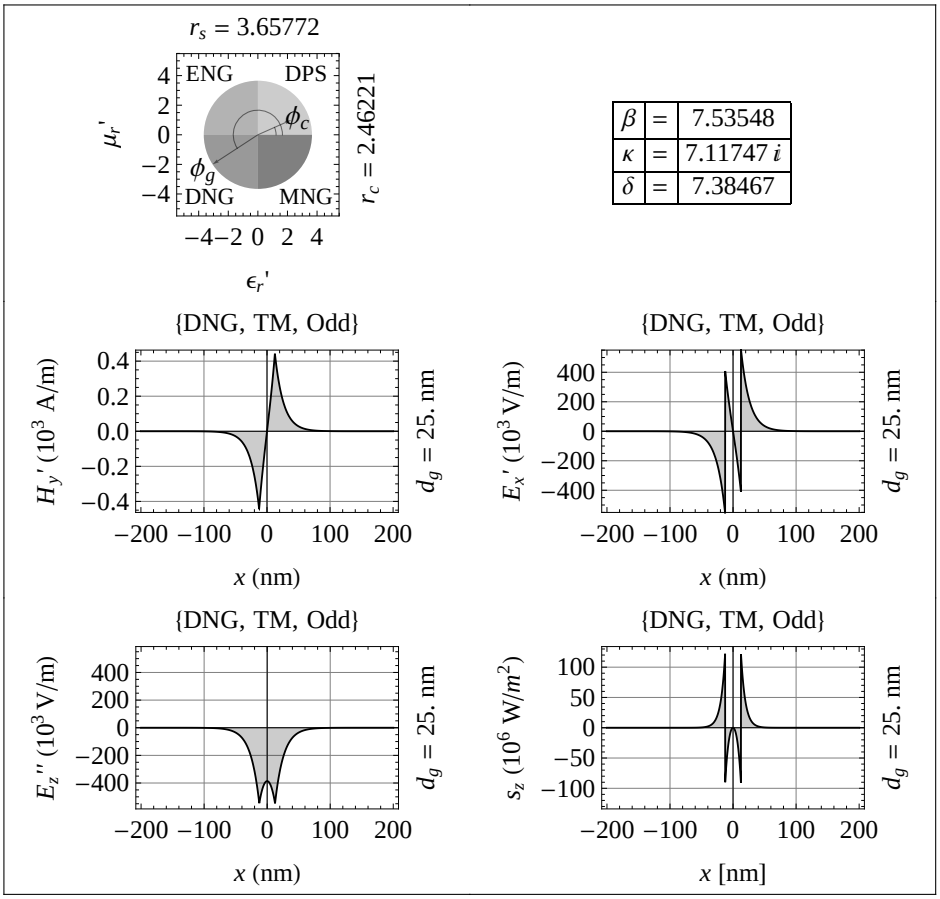

Fig. 5.22. The complete solution of an odd TM mode supported by a DPS/DNG/DPS-type structure with d_g= 25 nm.

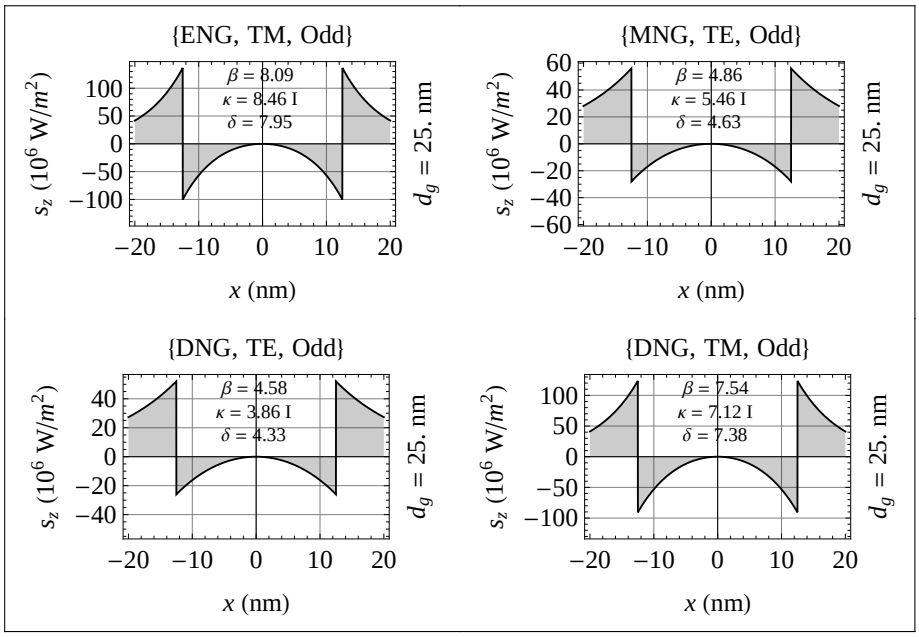

Fig. 5.23. The uniquely narrow profiles of the local power flow of odd modes supported by a guide with d_g= 25 nm. Here, shown clockwise from top left, is a TM mode of an ENG-type guide, a TE mode of an MNG-type guide, a TE mode of an MNG-type guide, and a TM mode of a DNG-type guide.

Exercises

(1) Table 5.1 includes only a partial list of the topics included in Table 2.2. Try addressing all the rest of the topics using the examples given in this chapter.

(2) Discuss the meaning of electric and magnetic charge density waves in the DPS/ENG/DPS-, DPS/DNG/DPS- and DPS/MNG/DPS-type structures in the context of a metamaterial.

References

[1] I. V. Shadrivov, A. A. Sukhorukov and Y. S. Kivshar. Guided modes in negative-refractive-index waveguides. *Phys. Rev. E* 67 (2003) 057602.

[2] M. J. Adams. *An Introduction to Optical Waveguides* (Wiley Interscience, 1981).