Designing meta material slabs exhibiting negative refraction using topology optimization

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Structural and Multidisciplinary Optimization

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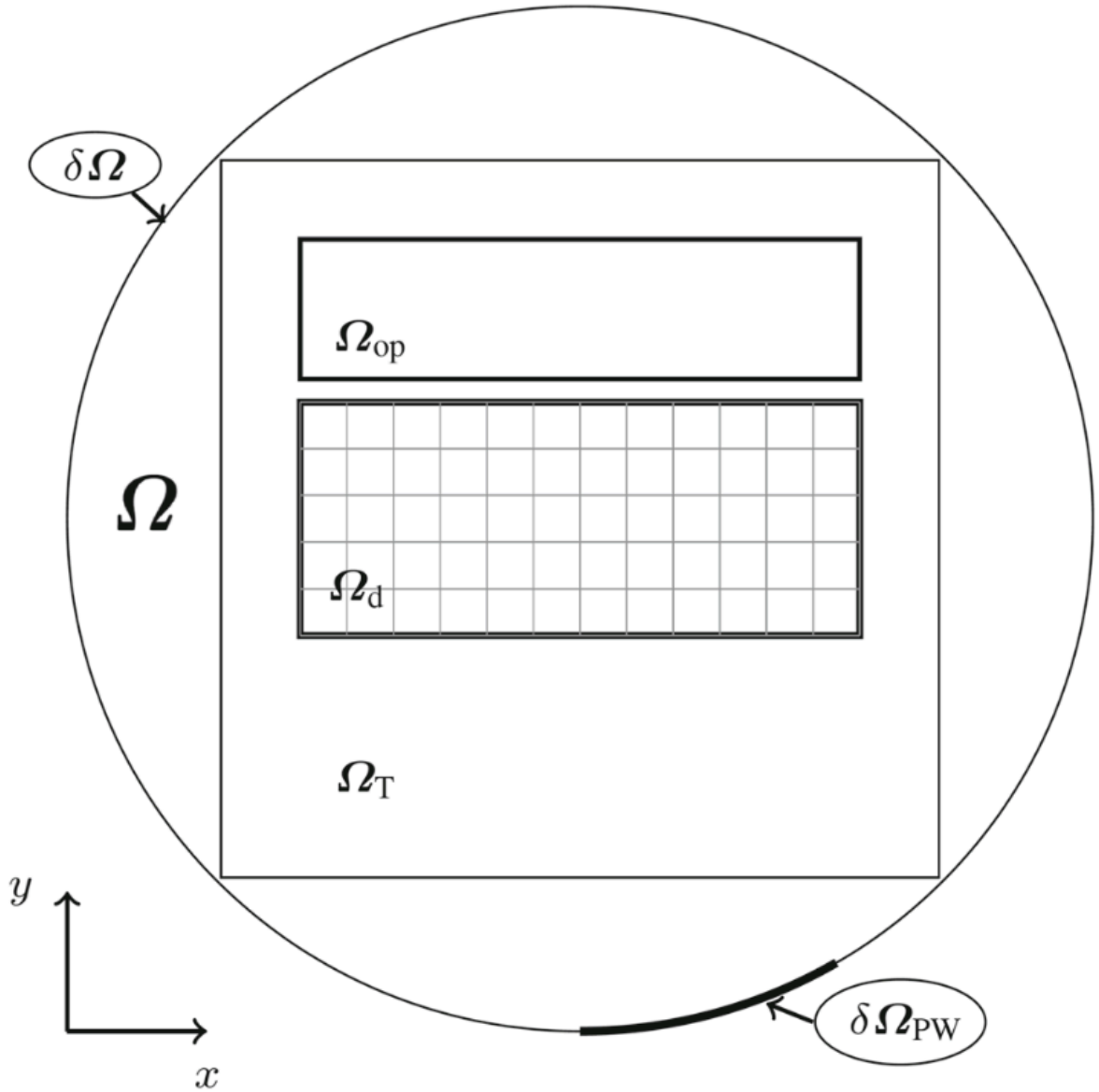

Fig. 1 Model problem sketch. Ω: Truncated Domain. Ω_{op}: Optimization domain. Ω_d : Design domain. $\delta\Omega$: Truncated Domain boundary. $\delta\Omega_{PW}$: Excitation boundary

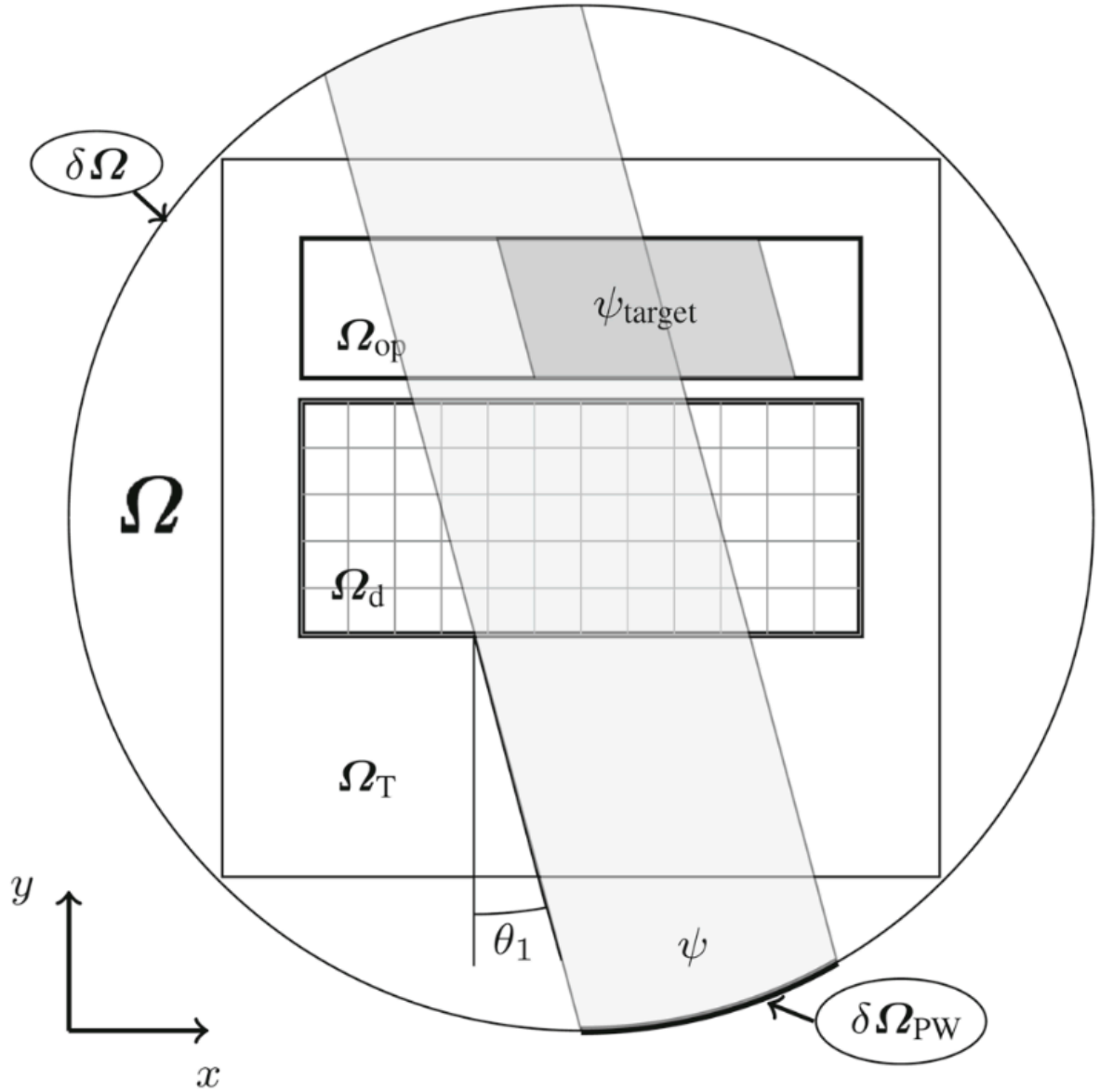

Fig. 2 ψ: Enveloped plane wave (Solution to (1)-(3)) and ψ_{target}: Target wave, overlaid on modeling domain. $\boldsymbol{\Omega}$: Truncated Domain. $\boldsymbol{\Omega}_{\text{op}}$: Optimization domain. $\boldsymbol{\Omega}_{\text{d}}$: Design domain. $\delta\boldsymbol{\Omega}$: Truncated Domain boundary. $\delta\boldsymbol{\Omega}_{\text{PW}}$: Excitation boundary

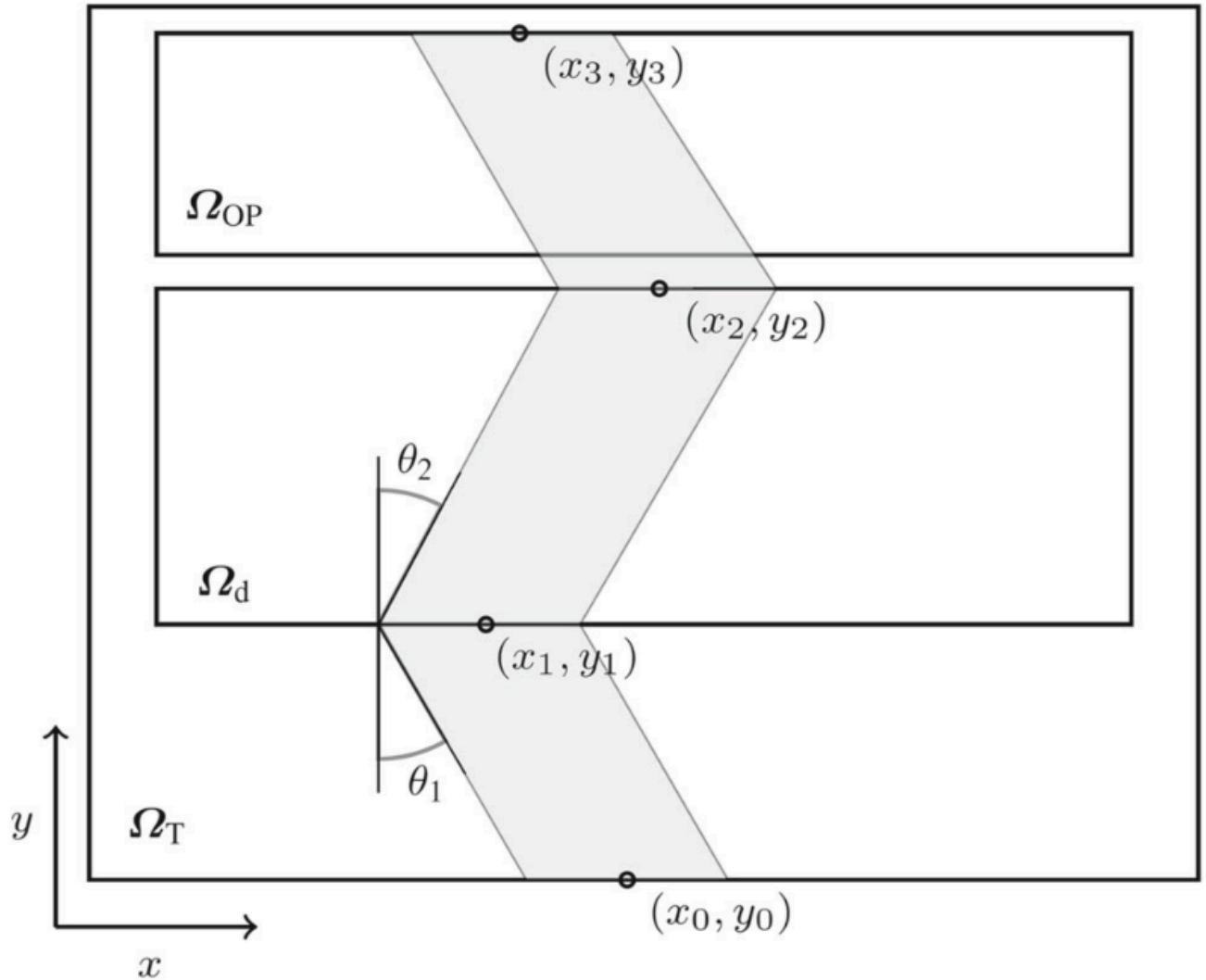

Fig. 3 Sketch of negative refraction of a beam entering the domain centered at $\langle x_0, y_0 \rangle$, including quantities needed to calculate the placement of the center of ψ_{target}, $\langle x_3, y_3 \rangle$, in order to obtain a desired n for a given θ_1

The objective function, Φ, to be minimized, is formulated based on the standard deviation, $\mathbf{STD}(x)$, between $|\psi|^2$ and $|\psi_{\text{target}}|^2$ and is defined on $\boldsymbol{\Omega}_{\text{OP}}$ as

$$\Phi = c_s \cdot \underset{\boldsymbol{\Omega}_{\text{OP}}}{\mathbf{STD}} \left(|\psi|^2 - |\psi_{\text{target}}|^2 \right), \tag{7}$$

$$\underset{\boldsymbol{\Omega}_{\text{OP}}}{\mathbf{STD}}(x) = c_s \cdot \frac{\int \left(x - \frac{\int x \, d\boldsymbol{\Omega}_{\text{OP}}}{\int d\boldsymbol{\Omega}_{\text{OP}}} \right)^2 d\boldsymbol{\Omega}_{\text{OP}}}{\int d\boldsymbol{\Omega}_{\text{OP}}}, \tag{8}$$

where c_s is a scaling parameter used to adjust the magnitude of Φ to improve the performance of the optimization algorithm. If Φ reaches a very low value it is beneficial to modify it by applying the natural logarithm to further improve the performance of the optimization algorithm.