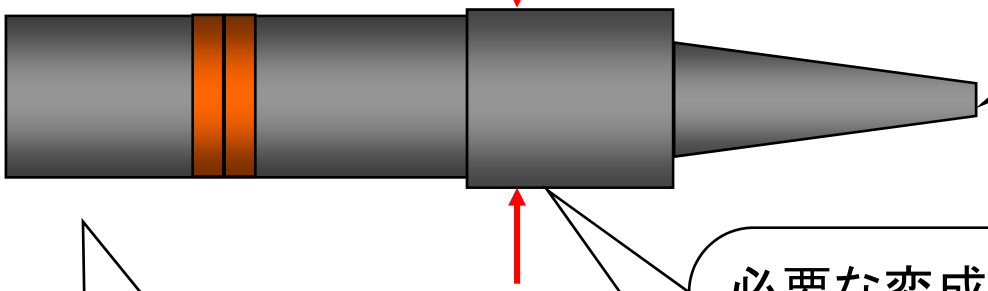
振動系の設計　Design of ultrasonic vibration system



最大外形＜1／4λ

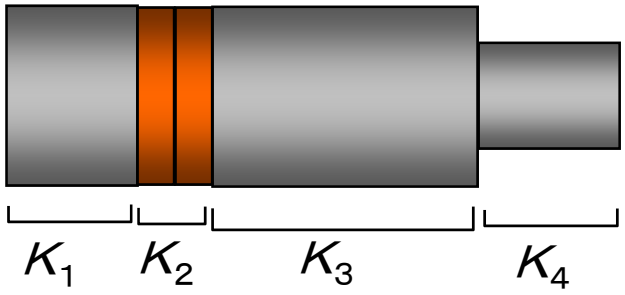
必要振動速度
必要機械出力

必要な変成比 Transformation ratio
材料強度と最大応力値 Max stress
機械損失 Mechanical loss
振動子最適負荷　Optimum load
加工性 How to fabricate?

必要な振動子の体格
最大振動速度
Max. velocity
Size

どこで支持するか How to hold
全長は？　重さは？ Length? Weight?
機械強度は？ Strength?

Procedure of analysis



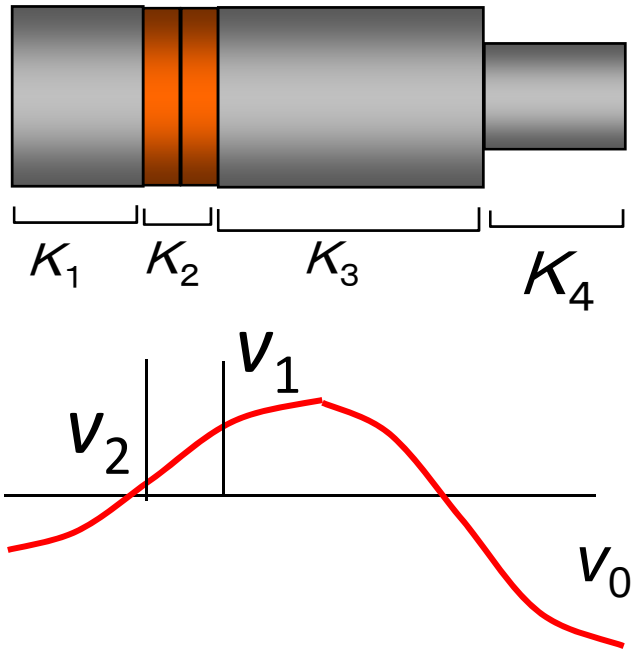
共振周波数は？ Resonance frequency?

振動分布は？ Vibration distribution?

等価回路は？ Equivalent circuit?

1. 4つの部分に分け、それぞれのK行列を作る。 Divide into four parts.
2. 4つの行列の積の行列を計算する。 Calculate the product
3. 両端自由（両端で力＝0）の条件から共振周波数を求める。Fine freq.
4. 行列を用いて、振動分布を出す。 Calculate the vibration distributions
   （各要素の境での力と振動速度）
5. 力の変成比がわかる。 Fine the transformation ratio.

Calculating the force factor



変成比 Transformation ratio

$$\phi = (v_1 - v_2) / v_0$$

Force factor of a singe PZT disk

A_{PZT}

$$A_{PZT} = eS / t$$

- e, Piezoelectric stress constant
- S, Cross section
- t, thickness of the PZT disk

Force factor

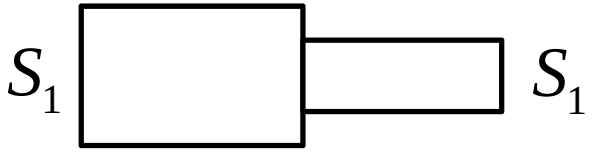
$$A = A_{PZT} \times \phi$$

振動分布から等価質量を求める。

Find the equivalent mass from the vibration distribution.

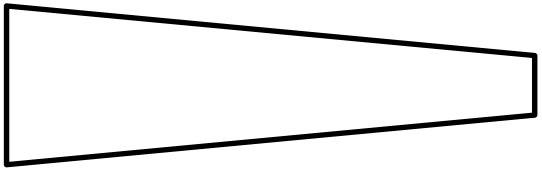
各種ホーン Horns

1）ステップホーン Stepped horn



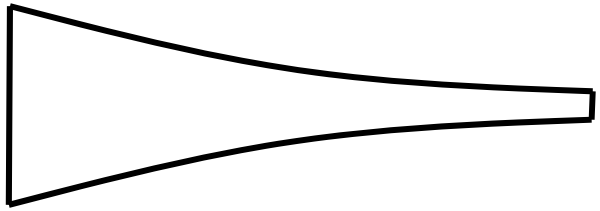
倍率 Transformation $\dfrac{S_2}{S_1} = K^2$

2）コニカルホーン（円錐） Conical horn



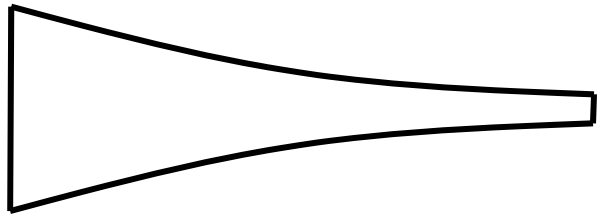
$S_x = \Omega x^2$ 倍率 $\dfrac{1}{\dfrac{\cos kl}{K}\left\{1+\dfrac{(K-1)\tan kl}{kl}\right\}}$

3）エキスポネンシャルホーン Exponential horn



$S_x = S_1 e^{\gamma x}$ 倍率 $\sqrt{\dfrac{S_2}{S_1}} = K$

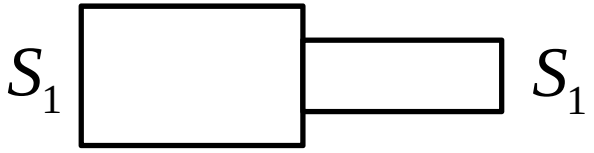
4）カテノイダルホーン Parabolic horn



$S_x = S_1 \cosh^2\left(\dfrac{x}{l}\right)$ 倍率 $\sqrt{\dfrac{S_2}{S_1}}\dfrac{1}{\cos kl}$

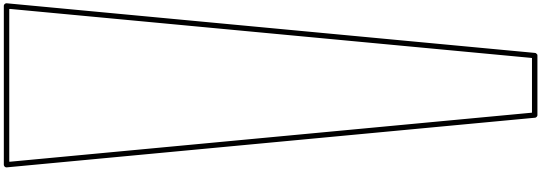
Characteristics of the horns

1）ステップホーン Stepped horn



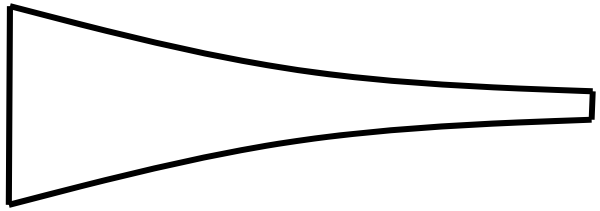
Easy fabrication, Limited ratio < 4
Stress concentration

2）コニカルホーン（円錐） Conical horn



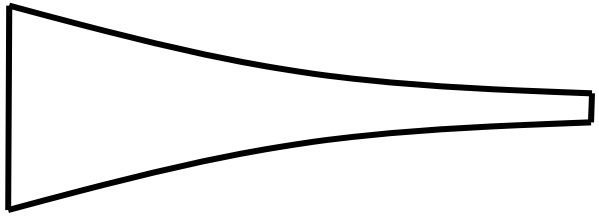
Distributed stress, small ratio

3）エキスポネンシャルホーン Exponential horn



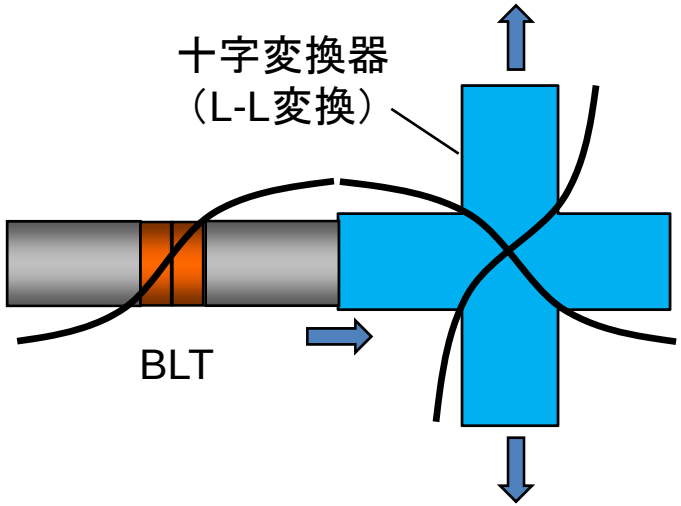
Moderate ratio, small stress concentration

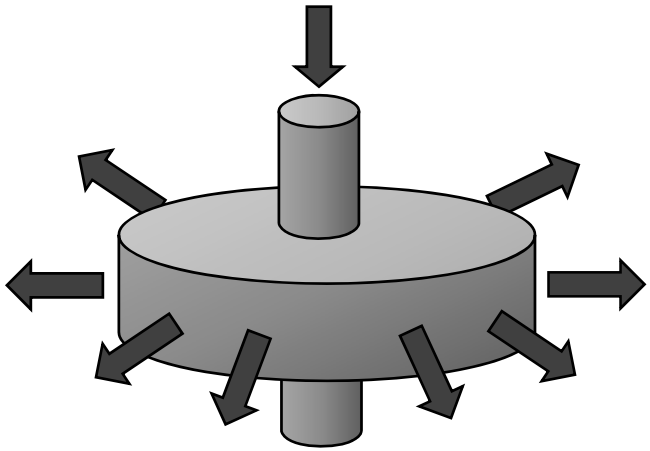
4）カテノイダルホーン　Parabolic horn

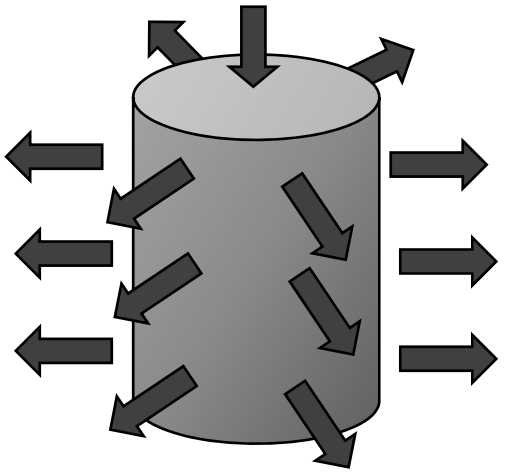


Large ratio, moderate
concentration of stress

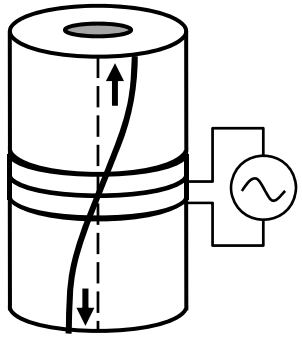
Direction converters





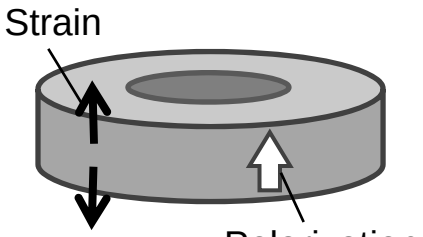


Different types of BLTs

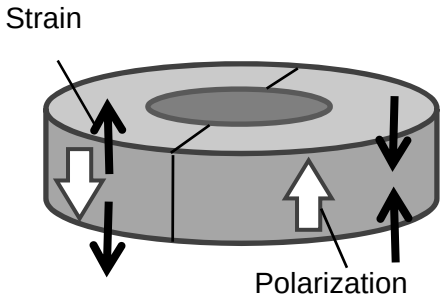


完成図

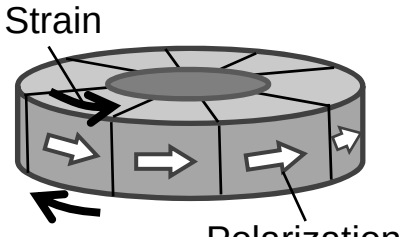
If the different type of PZT is used, the different type of vibration can be excited.



Longitudinal PZT



Bending PZT



Torsional PZT

Ultrasonic Radiators