Some consideration about processes of soliton formation from initially sinusoidal waveform in thin fiber of fused silica

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Abstract: Discussion is made for soliton formation in a thin fiber of fused silica. A tone-burst sinusoidal sound successively makes solitons from negative half-periods coming in order in the wave train. It is intended to discuss about difference of soliton formation process between two single sinusoidal pulses with negative period preceding and positive preceding. Operational treatment with nonlinear distortion operator and linear propagation operator are given.

INTRODUCTION

It has already found\(^1\) that tone-burst sinusoidal sound successively makes solitons from negative half periods coming in order in wave train. In this case, first soliton made from first negative period is the most stable among of the following solitons, because some disturbances caused by preceding positive pressure periods are delayed and superposed with following negative pressure period. Therefore, nonlinear distortion is affected. In this paper, it is intended to discuss about difference of soliton formation processes between two single sinusoidal pulses with negative period preceding and positive preceding.

OPERATIONAL PROCEDURE FOR SIMULATION

The simulation is made with computer algorithm introducing alternatively nonlinear procedure and linear propagation. The nonlinear procedure gives rise to waveform distortion and linear procedure is given by absorption and velocity dispersion. These procedures are realized by operators as shown in Fig.1, where NP[p(x,t)] means finite amplitude deformation and LP[F(x,ω)] is shown by

\[ LP[F(x+Δx,ω)] = F(x,ω)\exp(-j\Gamma Δx), \]

where NP and LP are nonlinear and linear operators for propagation Δx, respectively. F(x,ω) is Fourier spectrum at x and Γ is propagation constant. Four types of waveform shown in Fig.2 are used for comparison of soliton formation. Negative periods in

![Fig.1 Operation program of simulation for propagation with Δx.](image)

![Fig.2 Models used for discussion in this paper.](image)
(a), (b) and (d) can realize soliton, while positive periods in (a), (b) and (c) show only disturbances. Two types (a) and (b) are made by $p_1 + p_2$. For linear propagation, 
\[
LP[\mathcal{F}(x, \omega)] = LP[\mathcal{F}_1(x, \omega)] + LP[\mathcal{F}_2(x, \omega)]
\]  
(2)
is satisfied by eq. (1), where $\mathcal{F}$, $\mathcal{F}_1$ and $\mathcal{F}_2$ are Fourier spectra for $p_1 + p_2$, $p_1$ and $p_2$, respectively. On the other hand, nonlinear deformations of (a) and (b) do not always show the same change as $p_1 + p_2$. If $p_2$ being in (a) is overlapped with $p_1$ on the time axes, nonlinear operation is not same behavior as $p_1 + p_2$, that is, 
\[
NP[p] = NP[p_1 + p_2] \neq NP[p_1] + NP[p_2],
\]  
(3)and then 
\[
\mathcal{F}_n(x, \omega) \neq \mathcal{F}_1(x, \omega) + \mathcal{F}_2(x, \omega).
\]  
(4)If any overlapping in (b) are not realized, inequality appearing in eq. (3) & (4) disappear. This is the case of Fig. 3. $p(x, t)$ shows the same soliton as $p_1 + p_2$ and also the same Fourier spectrum as $\mathcal{F}_1 + \mathcal{F}_2$ as shown in Fig. 5. On the other hand, in Fig. 4, $p_2$ is overlapped with $p_1$, then deformation of $p(x, t)$ is not exactly same as the one of $p_1 + p_2$ , and the Fourier spectra are different, as shown in Fig. 6.