Coherent backscattering is a wave phenomenon that may initially seem surprising since it arises out of the coherence of a multitude of random scattering events. It manifests itself as an enhanced measured intensity of scattering off of a semi-infinite disordered medium of scatterers in the backward direction when averaged over many configurations of scatterers. It is typically considered a signature of ‘weak localization’, in contrast with ‘strong localization’, in which waves inside a very strongly scattering random medium are localized to a specific region due to interference effects. The strength of localization is characterized by forming the comparison of $k l$ with unity, where $k = \frac{2 \pi}{\lambda}$, $\lambda$ being the wavelength, and where $l$ is the elastic scattering mean free path in the scattering medium. If $k l \gg 1$ then the localization is weak. If $k l \sim 1$ then the localization is strong.

Coherent backscattering may be performed in many ways: the waves may be electrons scattering off of randomly embedded impurities in a metal, or they may be laser photons scattering inside of milk or a powder of GaAs. One of the main differences between the regimes that demarcate weak and strong localization is the density of scatterers since the scattering mean free path is inversely proportional to the density. Therefore, achieving strong localization requires creating an extremely dense scattering medium, such as could be done in a Bose-Einstein condensate of alkali atoms, each of whose cross section is far greater than its actual size. As a result, coherent backscattering experiments have recently been performed in cold un-condensed clouds of alkali atoms, as hopeful precursors to the
much sought after and contested goal of strong localization.

The aims of this document are to provide an introduction to the coherent backscattering phenomenon, first for scalar waves and simple scatterers, second for polarized waves and simple scatterers, and third for polarized waves and atoms with internal degeneracies. Adding each of these complexities in turn will allow us to identify their impacts individually in order to understand how the ideal coherent backscattering signal may be degraded when performed in a cold atom system, which holds the controllable-density, large scattering cross-section promise to achieve strong localization.

2 Scattering System Setup

In the most general sense, a scattering experiment is performed as shown in Fig.1. Waves with wave-vector \( \mathbf{k} \) are sent into a sea of scatterers that fill a semi-infinite half plane. For the moment, we treat the waves as scalar waves, i.e. they have no polarization vector. All scattering events in the medium are assumed to be elastic. We consider the weak scattering limit for which \( kl \gg 1 \), where \( l \) represents that elastic mean free path of the waves in the scattering medium. A detector measures the intensity reflected from the medium as a function of angle. Since all scattering is elastic, outgoing waves with wave-vector \( \mathbf{k}' \) have the same magnitude as \( \mathbf{k} \).

Our aim is to calculate the intensity that we expect to measure at the detector as a function of angle, \( \theta \), which subtends the vectors \( \mathbf{k} \) and \( \mathbf{k}' \). Therefore, we must first determine the probability amplitudes of all possible trajectories.

Though the complex amplitude for a wave to begin at one point and end up at another will be the sum of amplitudes for all possible trajectories, we will begin by considering one possible journey of a wave from source to detector. We will break down this journey into three legs:

(A) source to scattering medium;

(B) trajectory inside the scattering medium, starting at one specific spot and ending at another specific spot;

(C) scattering medium to detector;
as seen in Fig.2.

The probability amplitudes corresponding to the three legs of a wave’s possible journey are as follows:

(A) $e^{ik(R_i - R_s)}$, where $R_i$ denotes the position of the first encountered scatterer in the medium and $R_s$ indicates the location of the wave source,

(B) $ae^{i\delta}$, where $a$ is the amplitude for the path taken in the medium and $\delta$ is the phase accumulated along it,

(C) $e^{ik'(R_d - R_j)}$, where $R_j$ denotes the position of the final scatterer encountered before the wave leaves the medium, and $R_d$ indicates the location of the detector.
The total amplitude for this process is the product of the amplitudes of all three legs of the path: \((A)\ast(B)\ast(C)\).

If we consider (B) more carefully, we note that the amplitude to travel from \(R_i\) to \(R_j\) is really the SUM over ALL POSSIBLE PATHS’ amplitudes:

\[
A(R_i, t; R_j, t') = \sum_n a_n e^{i\delta_n},
\]

where \(n\) indexes each of the possible paths that the wave can take through the medium from \(R_i\) to \(R_j\).

If we consider path segments (A) and (C) more carefully, we note that the probability amplitude to send a wave \(k\) from \(R_s\) and receive its energy in wave \(k'\) at \(R_d\) must include the sum over all initial and final scattering points, \(R_i\) and \(R_j\). Thus the amplitude to send in wave-vector \(k\) from \(R_s\) at time \(t\) and detect wave-vector \(k'\) at \(R_d\) at time \(t'\) is given by

\[
B(k, t; k', t') = \sum_{i,j} A(R_i, t; R_j, t') e^{ik(R_i - R_s)} e^{ik'(R_d - R_j)}
\]

\[
= e^{-ikR_s} e^{ik'R_d} \sum_{i,j} A(R_i, t; R_j, t') e^{i(kR_i - k'R_j)}. \tag{2}
\]

3 Intensity at the Detector Plane

The detector measures intensity, therefore the quantity of interest is really \(|B|^2\), not \(B\) itself. When calculating the intensity, the constant phase factor that depends on the source and detector locations is cancelled by its complex conjugate. Thus, we obtain

\[
|B(k, t; k', t')|^2 = \sum_{i,j,l,m} A(R_i, t; R_j, t') A^*(R_l, t; R_m, t') e^{ik(R_i - R_l) + ik'(R_m - R_j)}. \tag{3}
\]

We can classify the terms in (3) into four categories according to the indices \(\{i,j,l,m\}\):

1. The general term for which none of the indices \(\{i,j,l,m\}\) are equal to one another, as is depicted in Fig. 3(a). These terms generate a random speckle pattern and we will call them collectively \(I_{\text{speckle}}\). Each term of this sort multiplies the probability amplitude for a wave to begin and end at specific points with the complex conjugate of the probability amplitude for an uncorrelated wave to begin and end at other specific points.
2. Single scattering terms, as depicted in Fig. 3(b). These terms represent the case in which all indices are equal to one another and where multiple waves interact with only a single scatterer. We write this term as

$$I_S = \sum_i |A(R_i, t; R_i, t')|^2.$$  \hspace{1cm} (4)

In this case, the magnitude squared of the probability amplitude for a wave to start and end at the same point spatially specifies the endpoints, but we further specify that only a single scattering event takes place. (The reasons for this will become clearer later on when we employ polarized waves.)

3. Multiple scattering terms for which multiple waves follow the same path through the medium, as depicted in Fig. 3(c). This occurs for $i = l, j = m$ and takes the form

$$I_L = \sum_{i,j} |A(R_i, t; R_j, t')|^2.$$ \hspace{1cm} (5)

Here, we exclude the single scattering events since they are contained within $I_S$. In this case we are taking the magnitude squared of the amplitude to start at a specific point and end at another as though two waves have incurred the same phase in travelling between these two specific points. One might ask about the validity of discussing two particular identical paths when the amplitude to begin at $R_i$ and end at $R_j$ is the sum of amplitudes for all possible paths joining these two points. What is most important is that the complex amplitude $A(R_i, t; R_j, t')$ be equal to $A(R_i, t; R_m, t')$, which is most likely to occur if $R_i = R_l$ and $R_j = R_m$. 

Figure 3:
Drawing isolated paths is merely a tool to visualize the process. It may be somewhat misleading without this caveat, however it is a standard descriptive method in the CBS literature.

4. Terms in which there is interference between time-reversed amplitudes, i.e. for which $i = m$, $j = l$ and $A(R_i, t; R_j, t') = A(R_j, t; R_i, t')$, a condition of time reversal. This case is depicted in Fig. 3(d) and may be written as

$$I_C = \sum_{i,j} A(R_i, t; R_j, t') A^*(R_j, t; R_i, t') e^{i(k+k') \cdot (R_i-R_j)}$$

It is very special because time-reversal allows us to proceed from the first to the second line of (6). Physically, $I_C$ represents the case in which two parallel waves incident on different points in the medium accumulate the same phase in the medium by tracing over each other’s paths in reverse to emerge at their respective partner’s entrance points, parallel once again. Though there is no real hierarchy between the two paths, one is usually referred to as the ‘direct’ path while the other is called the ‘reversed’ path. As for $I_L$, though we may picture specific overlapping paths, the complex amplitude to arrive at one point from another is the more accurate way to consider the concept.

Altogether, $I = I_{\text{speckle}} + I_S + I_L + I_C$. $I_S$ and $I_L$ are often referred to as ‘incoherent’, as they are written as the sum of intensities, i.e. the magnitude squared is taken before summing rather than after. On the other hand, $I_C$ is referred to as the coherent term since it has the same magnitude squared as $I_L$, but is modulated by a phase term. Note that thus far, our discussion has centered around two themes: index classification and time reversal symmetry.

If one performs a backscattering experiment by sweeping the detector position i.e. detecting the intensity as a function of angle from incidence, for a given configuration of scatterers, the trace is unremarkable. It provides a speckle pattern and there does not appear to be a specific dependence on $\theta$ (see Fig. 4). The accumulated phase is completely dependent on the random configuration of the scatterers and thus looks as though it varies randomly as a function of detection angle.
However, if the experiment is performed many times, each time with a different random configuration of scatterers, a distinct angle-dependent signal emerges in the average signal over all configurations. When we perform such an average over configurations, the $I_{\text{speckle}}$ contribution averages to zero since the phase, $e^{ik(R_i - R_l) + ik'(R_m - R_j)}$, of (3) is in general nonzero and varies randomly from one set of indices $\{i,j,l,m\}$ to another and from one configuration to another. The other three terms are the only ones that remain:

$$|B(k, t; k', t')|^2 = \sum_{i,j} |A(R_i, t; R_j, t')|^2 (1 + e^{i(k+k')(R_i - R_j)}).$$  \hspace{1cm} (7)

Note that the only angle-dependent term is the last one, the contribution from $I_C$. Since the aim is ultimately to observe a coherent process where it might seem counterintuitive to find such an occurrence, we might aim to maximize this contribution by looking at the case in which $-k' = k$. This is precisely the condition that gives rise to the phenomenon referred to as coherent backscattering, or CBS. As $\theta$ is increased from zero, the exponential in (7) will start to oscillate more and more rapidly and the average enhancement of the signal due to coherent backscattering will return to its background value.

Recall that $I_C$ arose by imposing time-reversal symmetry on the amplitude to go from a point $R_i$ to a point $R_j$ i.e. $A(R_i, t; R_j, t') = A(R_j, t; R_i, t')$. The more stringent condition for CBS requires not only this but also time-reversal symmetry of the amplitude to begin with $k$ and end with $k'$, namely $B(k, t; k', t') = B(-k', t; -k, t')$. Figure 5 compares these two cases of $-k' \neq k$ and $-k' = k$. One notes that in the former case, the two interfering paths have identical ingoing wave-vectors and identical outgoing wave-vectors. However, in the latter case, not only is this true but the ingoing and outgoing wave-vectors are anti-parallel.
Figure 5:

4 Enhancement factor

The CBS enhancement factor is defined as

$$\alpha = \frac{\text{total average intensity}}{\text{total average intensity far from } \theta = 0} = \frac{I_L + I_S + I_C(\theta)}{I_S + I_L}$$

where the intensities refer to those averaged over many configurations of scatterers (hence the absence of \(I_{\text{speckle}}\)). The form of \(\alpha\) is as shown in Fig. 6: it has a normalized background level of 1, and it rises to a sharp peak at 2 where the CBS condition is fulfilled.

Figure 6:

Note that if we consider the intensities for a single direct multiple-scattering path and its reverse as in Fig. 5(a), we obtain

$$I_{\text{tot}} = \frac{|A_{\text{dir}}|^2 + |A_{\text{rev}}|^2 + 2|A_{\text{dir}}||A_{\text{rev}}| \cos[(k + k') \cdot (R_i - R_j)]}{I_L + I_C}.$$  \hspace{1cm} (9)

where the first two terms represent the intensity detected from each of the paths independently and the second term arises from the interference between the two paths.
Since time reversal symmetry implies that the two trajectories in the medium have equal amplitudes ($R_{i,\text{dir}} = R_{j,\text{rev}}$ and $R_{j,\text{dir}} = R_{i,\text{rev}}$ yield $A_{\text{rev}} = A_{\text{dir}}$), the expression may be simplified to $I_{\text{tot}} = 2|A_{\text{dir}}|^2(1 + \cos[(k + k') \cdot (R_i - R_j)])$. If we aim to describe backscattering intensity parallel to the incident axis, i.e. Fig. 5(b) rather than (a), then the expression may be simplified even further. Because antiparallel ingoing and outgoing wave-vectors ($k = -k'$) result in maximum constructive interference, $I_C$ becomes equal to $I_L$, i.e. $I_{\text{tot}}(k, k') = I_{\text{tot}}(k, -k) = 4|A_{\text{dir}}|^2$. Note that $I_S$ is absent because, in this illustrative example, we are only considering a path that contains multiple scattering events.

We now note the important result that

$$I_C \leq I_L \quad (10)$$

and that $I_C = I_L$ if and only if the condition for CBS, $-k' = k$, is met. Thus, to maximize the enhancement factor, we would ideally like to attain this aforementioned equality and minimize the single-scattering contribution.

If there weren’t time reversal symmetry, the contrast of enhancement factor would be reduced, as (10) would remain strictly an inequality. We will revisit this issue later on.

5 Summary: So far …

- When looking at reflected waves from a multiply scattering medium, there are three distinct contributions to the configuration-averaged intensity: $I_S$, $I_L$, and $I_C$.

- We are most interested in $I_C$, the contribution that relies on interference: the CBS intensity.

- This interference term relies on time reversal symmetry: it arises from the interference of time reversed paths as seen in right-hand panel of Fig. 5.

- In order to see the evidence of interference, we must average the intensity over many configurations of scatterers.
6 Wave Polarization and CBS

If we consider waves with polarization rather than scalar waves, we must revisit the contributions to the single scattering intensity, $I_S$, and to the coherent (CBS) scattering intensity, $I_C$. We will see how single scattering events, which decrease the contrast of the CBS signal in $\alpha$, may be suppressed for some outgoing wave polarizations (with respect to particular ingoing polarizations). We will also see how there are fewer contributions to $I_C$ for polarized waves than there are for scalar waves because particular relationships between ingoing and outgoing wave polarization must exist in order to obtain equal direct and reversed amplitudes according to time reversal symmetry. Over the course of this section, we will treat the scatterers as classical, that is to say that their wave scattering properties are akin to those of classical scatterers of electromagnetic radiation, as is explained further below.

6.1 Wave Polarization and Single Scattering

The scattering of polarized light waves, whether considered classically or quantum mechanically, occurs according to the appropriate electric field radiation pattern. In classical electromagnetism, the outgoing electric vector field is proportional to $p - n(n \cdot p)$, where $p$ represents the polarization vector of the incoming wave and $n$ represents the normalized outgoing wave-vector. The magnitude squared of this field, as a function of solid angle, describes the power distribution of scattered radiation in $4\pi$ steradians. In quantum mechanics, one may use a Wigner-Weisskopf formalism to derive the photon wavefunction, however the corresponding classically obtained radiation field pattern also describes the quantum mechanical wavefunction of the scattered photon. (The classical power distribution describes the quantum mechanical probability of a photon exiting in a given mode.) When considering the scattering of a single photon, the outgoing wavefunction conserves quantities such as angular momentum. However, a detector at an arbitrary location will measure the arrival of a scattered photon whose polarization in the lab frame differs from that of the photon originally incident on the scatterer. Though these two statements may seem contradictory, they may be reconciled by considering that the detector does not tell us about the entire scattered photon wavefunction. It only tells us about a small portion
Thus, for a given incident photon with well-defined wave-vector and polarization, we may predict the polarization of the scattered photon in a given scattered direction. For example, as illustrated in the dipole radiation pattern for incident linearly polarized waves in Fig. 7, a linearly polarized incident photon will always scatter into a linearly polarized outgoing mode with respect to \( \mathbf{n} \). Also as seen in Fig. 7, scattering at 90° is not allowed in the direction parallel to \( \mathbf{p} \), but outgoing polarization is linear and parallel to \( \mathbf{p} \) when the outgoing wave-vector is perpendicular to \( \mathbf{p} \). Hence, in the backscattering direction, incident linearly polarized waves will scatter linearly polarized waves whose polarization is parallel to that of the incident wave’s.

![Dipole radiation pattern for incident linearly polarized waves](image)

**Figure 7:**

One can similarly determine the radiation and polarization pattern for circularly polarized waves, though it seems to be a less commonly given example. Most importantly, it turns out that when circularly polarized waves are incident on a scatterer, backscattered waves return with the same polarization. Polarization of a wave is expressed with respect to the lab frame, but helicity is also commonly used to characterize circularly polarized waves. By helicity, we refer to the sense of rotation of the polarization vector with respect to the wave’s propagation direction. In that case, circularly polarized waves will backscatter with helicity opposite to the entering helicity. (Incidentally, forward scattering preserves helicity, and 90° scattering yields linearly polarized waves.)

According to these two aforementioned examples, we may assert that during a single scattering event for both linearly or circularly polarized waves i.e. when only a single scatterer is implicated, polarization of the scattered wave will be preserved (recall that
the helicity relation will be opposite to the polarization relation for backscattering). This implies that linearly polarized incident waves will be backscattered into a parallel linearly polarized mode, which we denote in shorthand lin∥lin, and that a circularly polarized mode will be backscattered into another circularly polarized mode of opposite helicity, i.e. h⊥h. This also implies that the two other so-called ‘polarization channels’, namely lin⊥lin and h∥h, are not accessible for a single scattering process.

Since, as we have just seen, $I_S$ is polarization-dependent, it is conventional to perform CBS experiments reviewing each of the four above-mentioned polarization channels separately. In practice, to do this, a wave with well-defined polarization is sent into the sample, and a polarization analyzer is placed in the detection path so that only one channel is examined at a time.

One might ask why the aforementioned constraints do not apply to $I_L$ since multiple scattering events seem like a string of single scattering events. When a single scattering event results in an outgoing wave in some arbitrary direction rather than the backscattering direction, the polarization of the outgoing wave will be that which is defined by the aforementioned expression, $p - n(n \cdot p)$. Should this arbitrary direction be some other than the backscattering direction, the prescribed outgoing polarization may be different altogether than the ingoing polarization. A series of such events resulting finally in an outgoing wave in the backscattering direction will thus not be subject to the same constraint as are the contributing waves to $I_S$. This is illustrated in Fig. 8, which compares a single and double scattering process. Circularly polarized waves will scatter linearly polarized waves for a 90° exit angle, and so the double scattering process results in linearly polarized light being backscattered, contrary to the single scattering h⊥h result. Likewise, for a series of scattering events, the ‘jagged’ path traced as a result of multiple scattering events, each in a random direction, relaxes the constraint that we impose for single scattering in the backscattering direction.

The polarization considerations for $I_S$ are summarized in the table below:
Recall that the CBS enhancement factor (8) is maximized when $I_S$ is minimized. Therefore, to enhance $\alpha$, it seems appropriate to choose a polarization channel for which $I_S = 0$.

### 6.2 Wave Polarization for CBS under Time Reversal Symmetry

The aim in detecting the CBS signal is always to maximize the contribution from interfering time-reversed paths. For two waves to maximally interfere, their amplitudes must be equal. This is still assured as a consequence of time reversal symmetry for polarized waves, however the amplitude for a given scattering sequence must take into account initial and final polarization states of the waves, $\epsilon$ and $\epsilon'$, not just the initial and final wave-vectors, $\mathbf{k}$ and $\mathbf{k}'$.

Recall that the CBS signal arises from interference between time-reversed paths. Thus, the question we must answer is “What is the relation between the time-reversed polarizations and the direct wave’s polarization?” Answering this question is akin to filling in the

<table>
<thead>
<tr>
<th>Polarization channel</th>
<th>$I_S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>lin</td>
<td></td>
</tr>
<tr>
<td>h⊥h</td>
<td>$&gt; 0$</td>
</tr>
<tr>
<td>lin⊥lin</td>
<td>0</td>
</tr>
<tr>
<td>h</td>
<td></td>
</tr>
</tbody>
</table>
blanks in Fig. 9 and may be accomplished by considering two facts, depicted schematically in Fig. 10:

Figure 9:

(a) Time reversal is more accurately described as ‘motion’ reversal and thus requires that momentum and angular momentum both be reversed. We will consider circularly polarized waves to illustrate the relevance of this concept to CBS. In characterizing time-reversed waves, the sense of rotation of the polarization vector, which is described with respect to a fixed coordinate system (as opposed to helicity, which is determined with respect to the direction of the wave-vector) is reversed. Reversing the rotation is equivalent to taking the complex conjugate of the original polarization. Thus, as illustrated in Fig. 10(a), the polarization associated with $-k'$ must be $\epsilon'^*$ since it provides the rotation reversal of $\epsilon'$ for circularly polarized waves. This corresponds to preservation of helicity ($h||h$) in the case of backscattering. One can use the same argument for linearly polarized waves in which case parallel linear polarization is backscattered ($\text{lin}||\text{lin}$).

(b) Since the reversed path is equivalent to the time-reversed direct path, the ingoing wave-vectors ($k$ for the direct path, and $-k'$ for the reverse path) must have the same polarization. Therefore, as illustrated in Fig. 10(b), if the polarization associated with wave-vector $k$ is $\epsilon$, then the polarization vector associated with $-k'$ must also be $\epsilon$. 
Combining statement (a) with statement (b) requires that:

\[ \epsilon = \epsilon' \quad \text{or} \quad \epsilon^* = \epsilon'. \]  

(11)

Formally,

\[ A_{\text{dir}} = A(k, \epsilon \rightarrow k', \epsilon') = T A(k, \epsilon \rightarrow k', \epsilon') = A(-k', \epsilon^* \rightarrow -k, \epsilon^*') = A_{\text{rev}}, \]  

(12)

where \( T \) represents the time reversal operator. As may be verified, the action of the time reversal operator is to change the sign of the wave-vectors, take the complex conjugate of the polarization vectors, and reverse the direction of the arrow.

In words, the probability amplitude for direct and reversed paths will be equal due to time reversal, provided that the two scattering paths obey the polarization constraints indicated in (11). Diagrammatically, we may examine the concrete case of the double-scattering paths depicted in Fig.11. Fig.11(a) and (b) show two double scattering paths that are both possible according to the scattering theory discussed in the previous section. Note that they terminate similarly. Fig.11(c) shows the time-reverse of Fig.11(a) and therefore the amplitudes for (a) and (c) are equal. However, it can be seen that it is not possible to generate a time-reverse of (b) while still satisfying the constraints of the scattering theory of polarized waves. Whereas, (c) would be an adequate time-reverse of (b) if we were only considering the waves as scalar, the amplitudes for processes (b) and (c) need not be equal when polarization is considered. This illustrates how the CBS signal is diminished from its ideal potential when polarized waves are considered: not all paths that appear to be the time-reverse of one another according to their wave-vectors alone will satisfy the time-reversal condition when polarization is included.

The added polarization condition described by (11) and (12) restricts the possibility of time-reversed paths to the \( \text{lin}||\text{lin} \) and \( \text{h}||\text{h} \) channels. In other words, \( I_C \) can only have
a maximum value of $I_L$ in those two channels. In the orthogonal channels, since the polarization conditions for time reversal cannot be met, amplitudes $A_{\text{dir}}$ and $A_{\text{rev}}$ will not generally be equal. We saw in (9) that such an inequality served to reduce the ratio of $I_C/I_L$ in the scalar wave case, and it will still be true when polarization is taken into account. This presents a more stringent requirement, as there will be instances in which the constraints on wave-vectors are met but in which the constraints on polarization are not, as was indicated in Fig.11.

The following table summarizes the polarization results for $I_C$, where $I_{C_{\text{max}}} = I_L$:

<table>
<thead>
<tr>
<th>Polarization channel</th>
<th>$I_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>lin∥lin</td>
<td>$I_{C_{\text{max}}}$</td>
</tr>
<tr>
<td>h⊥h</td>
<td>$&lt; I_{C_{\text{max}}}$</td>
</tr>
<tr>
<td>lin⊥lin</td>
<td>$&lt; I_{C_{\text{max}}}$</td>
</tr>
<tr>
<td>h∥h</td>
<td>$I_{C_{\text{max}}}$</td>
</tr>
</tbody>
</table>

Therefore, to maximize the enhancement factor, we wish to look at the parallel channels.

Combining all that we have learned from our polarization considerations, only the h∥h channel can achieve $\alpha = 2$, as it is the only channel for which both single scattering is
not permitted and the CBS signal is maximized. All other channels will have $1 < \alpha < 2$. This underscores the importance of looking at the signal channel by channel.

7 Summary: CBS and Polarization ...

- Polarized waves have stricter constraints for time reversal symmetry, the process responsible for CBS.

- CBS will only occur, for simple scatterers, in the parallel channels.

- Single scattering (which reduces $\alpha$) only occurs in the lin$\parallel$lin and h$\perp$h channels.

- These facts make h$\parallel$h the preferred channel for observing CBS of polarized waves off of simple scatterers.